Soldering Brazing

& the Joining of Metals

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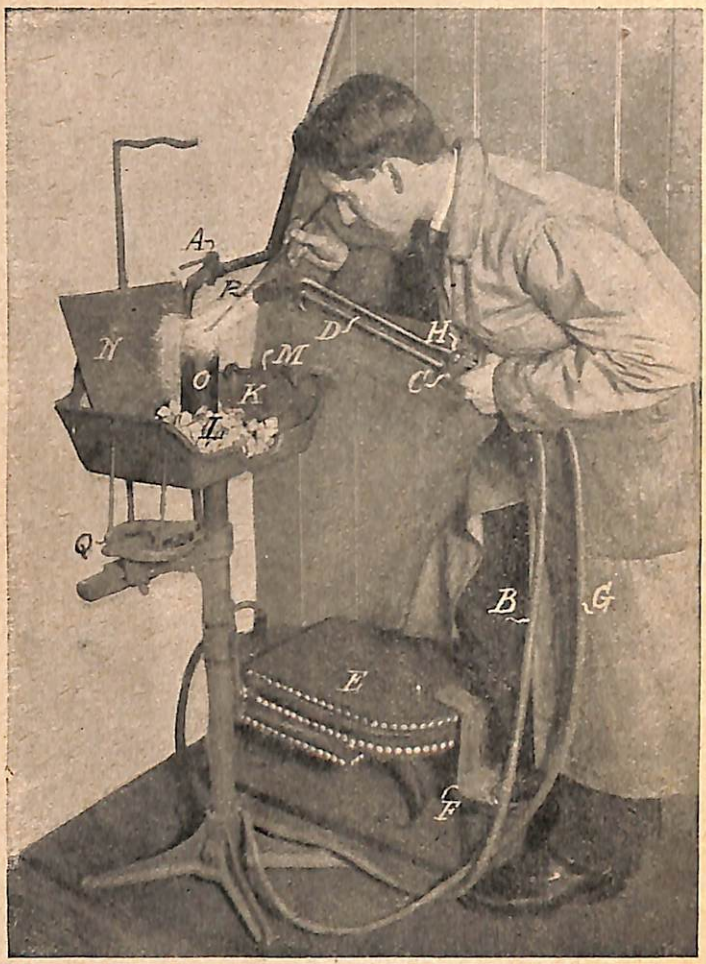
SOLDERING, BRAZING AND THE JOINING OF METALS



[*Frontispiece.*

The General Process of Hard Soldering a Small Boiler

A, Gas cock. B, Flexible gas tube. C, Gas regulator. D, Blowpipe. E, Foot bellows. F, Treadle. G, Flexible air tube. H, Air regulator. K, Brazing hearth. L, Asbestos nuts. M, Receptacle for flux, etc. N, Firebrick or plate hearth back. O, The boiler shell. P, Amalgamated rod. Q, A bracket for blowlamp.

The bracket over the hearth is for supporting large work, such as cycle frame parts.

SOLDERING, BRAZING AND THE JOINING OF METALS

A practical handbook of instruction in everyday workshop processes

BY

THOMAS BOLAS, F.C.S., F.I.C.

Revised and enlarged edition by

GEORGE GENTRY

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PUBLISHERS' NOTE

PROFESSIONAL and amateur workshop mechanics, model engineers, apprentices and students have in the past found a smaller handbook on this subject of considerable interest and practical help. Readers' expressions of satisfaction have encouraged the publishers to issue, in this volume, a more detailed presentation of the subject. The scope has been widened and much new matter added, with additional illustrations. It is hoped that readers, new and old, will find, and continue to find in this book an aid to their craft and incentive to their enthusiasm.

PREFACE TO ENLARGED EDITION

THIS handbook was first extended to include auto gas bits, blowpipe soldering, electric cable jointing, contact facing, model boiler brazing, smith's welding and metal decoration. It is now divided into eleven chapters, which deal in order with: General principles of soldering; equipment for soft soldering; bit soldering and general heat soldering of large articles; soft soldering tinplate, ironware, zinc and lead, followed by the soldering and wiping of pipe joints; brazing and hard soldering as applied in model work; soldering of precious metals and refractory materials; burning together and welding and soldering with tin foil in fine plating and metal decoration.

Important additions are descriptions of modern electrically heated bits, and detail descriptions of smith's welding, and electric spot and butt welding methods and apparatus. Except in the last two, production methods of metal joining have not been enlarged upon, as they are essentially trade methods, which demonstrate the application of the first principles contained herein as applied directly to quantity. The specialist's job of high-heat power blowpipe burning and welding is mentioned in order to complete the list, but the book as a whole now covers all branches of its title subjects. The tyro will still find that practice in this branch of craftsmanship is the basis of success in joining metals.

CONTENTS

	PAGE
Preface	6
Chapter I. General Principles of Soldering	9
Chapter II. Equipment and Materials for Soldering	14
Chapter III. Soft Soldering with a "Bit"	33
Chapter IV. Soft Soldering Large Articles	36
Chapter V. Soft Soldering Tinplate, Ironware, Zinc, and Lead	41
Chapter VI. Soldering with Tin-Foil	45
Chapter VII. Electric Wire and Cable Jointing ..	49
Chapter VIII. Pipe Joints: Soldering and "Wiping"	57
Chapter IX. Brazing or Hard Soldering	62
Chapter X. Soldering Precious and Refractory Metals : Electrotype Joints : Glass to Metal	71
Chapter XI. Burning Together, and Various Methods of Welding	75

SOLDERING AND BRAZING

CHAPTER I

GENERAL PRINCIPLES OF SOLDERING

THE art of soldering metals is popularly stated to be "a process of uniting separate metallic parts by means of a metallic cement in a state of fusion." This description is an excellent one for purposes of etymological definition, but for all practical purposes it is decidedly misleading, as it misses the main point and perpetuates the idea that solder is a kind of adhesive which acts similarly to gelatinous and resinous glues, as well as stone cements. For the purpose of this handbook, which is intended as a practical guide to amateurs and others who wish to become proficient in soldering, the process may be better described as a method of joining metals by superficially amalgamating separate metallic parts with an alloy which fuses at a lower temperature than those parts, the parts being either simultaneously or afterwards fused and frozen together by means of the intermediate alloy. Thus it will be seen that there is only one other process of joining material which resembles soldering, and that is welding, and the main difference in these is due to the fact that, so far as the solder—the uniting metal—is concerned, in the latter process the metallic parts are autogenous. In other words they are their own solder, hence the amalgamating part of the process is absent and it only remains to fuse and freeze together the parts by their own metal, which is correspondingly difficult, due to the fact that the fusing-point of the

whole part is the same as that required to effect the joint. Again, welding nearly always only applies to commercially pure metals and not to alloys, whereas solder not only applies to metals but alloys also, and always effects the jointing by means of an alloy.

Metals and Alloys Defined

It may be well here to define metals and alloys. The popular and original idea of the difference between a metal and an alloy has been that the former is a pure metallic element such as platinum, gold, silver, copper, iron, etc., and the latter an admixture by interfusion with any of the above of any quantity of a baser metal than itself, the notion of an alloy being therefore regarded as adulterating precious metals with baser varieties. From the mechanic's point of view, therefore, it is better to make clear that *commercially* pure metal may be regarded as metal which is alloyed with other metals or elements to give it necessary durability or characteristics. For instance, mild steel and wrought iron may be regarded as metals, but both are an admixture of iron and carbon ; yet neither can be called an alloy. Similarly, standard gold ranks as a metal, yet it is an admixture of 22 parts by weight of gold to 2 of copper or silver, according to the colour required. Commercial copper is very nearly pure, whereas commercial zinc has no claim whatever to purity, yet it ranks as a metal. The commercial alloys include such as 18-carat gold and under, containing 18 parts by weight of gold to 6 of baser metal, 15 carat having 15 to 9, and so on. The various kinds of brass are mostly compounds of copper and tin, or copper and zinc, or all three ; also bearing metals (white metal) which contain the same with the addition of lead, the white elements preponderating over the copper ; that is to say, the zinc, tin, or lead. In addition may be mentioned pewter, which is tin and lead. Of course there are other metals and alloys, but they need not be mentioned here.

Among the above alloys certain kinds of brass containing relative proportions of copper and zinc are called spelter or brazing solder. This is used for soldering copper, brass, iron, and steel, and the same with the addition of gold or silver forms hard solder for uniting gold or silver as the case may be. The soft solders resemble pewter, being composed of tin and lead, having rather more of the latter and less of the former than pewter These are used for uniting copper, brass, zinc, iron, and steel, and sometimes silver. From the above three groups of solder two soldering processes are worked. The first two, carried out by means of the more intense heat such as by the gas blowpipe, and resulting in a more durable joint capable of resisting correspondingly higher temperatures, are known as hard soldering. The last mentioned, carried out by less intense heat more generally applied by a soldering bit, is known as soft soldering and can be applied to any metal, with the exception of aluminium. There are methods of soldering aluminium, but from the point of view of durability of joint and for general wear and tear, these have not been found very satisfactory.

Fusion and Freezing

To make clear the reference to fusion and freezing. The point at which this takes place varies considerably for different metals, as is well known, and for practical purposes we may regard the liquid state of general substances as the same as the molten state of metals—that is, as a state of fusion. Hence the fusion point of mercury is – 38° F., water 32° F., and iron 2740° F. And at average temperature (60° F.) mercury and water are in a state of fusion, and iron frozen. Mercury is the only metal which can be handled in a state of fusion, and it therefore presents a suitable means of experimenting to demonstrate what is meant by amalgamating. If, therefore, the reader obtains a small quantity of mercury he will be able to make clear to himself that under certain conditions a molten metal will amalgamate ; that is

to say, alloy with a solid metal or alloy by merely bringing the two together. The conditions are the most important part of this and of the whole matter of making soldered joints. To demonstrate, procure some short lengths of copper, brass, zinc, and German silver wire and first render the points of them mechanically clean. This can be effected by filing bright with a clean file ; next dip any one of them into the mercury, breaking through any skin or deposit of slag on the surface. Globules of mercury may adhere, but will almost surely run off or easily wipe off the bright surface of the wire. Then apply a single drop of hydrochloric acid by touching the wire against the wet stopper of the acid bottle and immediately dip again into the mercury. The amalgamation will be apparent directly it is removed, for, although the superfluous mercury will run off, some will be found to adhere, and not only adhere but enter into composition with the wire so that it cannot be rubbed off. This power of amalgamation is peculiarly a property of mercury, because at ordinary temperatures it is the only metal which exists in a state of fusion, for, once having the start, it will go in and pass right through some metals and alloys. If, indeed, it be added in excess, it will disassociate the metal and dissolve it, thus forming a metallic paste known as amalgam.

Flux

Should you care to test the effect of mercury upon a filed surface of pewter or of soft solder, you will find that it readily alloys with the metal without the acid treatment ; on the other hand, it does not alloy with steel or iron, but it readily alloys with zinc, using acid, and will not affect platinum at all. Consequently, we see that this power of amalgamating varies with different metals, and it can be safely assumed that if two amalgamated surfaces be joined with an excess of mercury, and the temperature carried down below the freezing-point of mercury, the joint will solidify and form practically a soldered joint, which will be more or

less durable according to the strength of mercury when in a solid state; and also will be correspondingly unstable, due to its low melting-point.

The consideration of this property of mercury will bring home to the novice more than anything else what he is aiming at when trying to solder, and the difficulty he may experience in endeavouring to amalgamate is really increased in soldering. Firstly, the high temperature necessary tends more rapidly to oxidise the prepared surfaces, and secondly, the necessity of maintaining the temperature adds to the labour and also prevents manipulation of the work. It is absolutely necessary, therefore, to use in soldering some material which will protect both the metal and the solder from the action of the air, and also to reduce any oxide formed. This material is called a flux.

CHAPTER II

EQUIPMENT AND MATERIALS FOR SOLDERING

It is proposed in a series of paragraphs to deal firstly with the various materials and appliances employed in the most usual and ordinary work. Then, having laid a groundwork by this general instruction, to discuss modifications, appliances, materials, and methods which, if introduced in the first place, would make the study of soft soldering very confusing to the beginner.

The Soldering Bit or Bolt

The beginner who obtains a single bit should purchase the old-fashioned form which is shown on the left in the group (fig. 1). This bit is a somewhat pointed, short, and thick piece of copper rod, mounted in a cleft at one end of a slender iron stem : the iron stem is fitted to a wooden pad or handle. The hot copper end being first well amalgamated with the melted solder, or "tinned," as the workman terms it, the soldering bit becomes a very convenient tool for carrying small doses of solder to the work, as a good deal of solder will hang on to the bit by capillarity. If, while the point of the bit is laid against the work to be soldered, a stick of solder is held against the amalgamated side of the bit, the solder will melt and run down in a steady, slow stream; while, if the bit is drawn forward, an even line of soldering results.

In finishing a joint thus, it will be found better to poise the bit so that it does not touch the work (*i.e.* the actual surface being soldered), after the latter has become sufficiently heated to take the solder ; and so to run an even line of

liquid solder, in which the point or edge of the bit is just immersed. By this means a much neater job will be made of the joint and the solder more evenly distributed than if the bit were pressed hard against the work.

In this method it will be noticed that the solder itself is the medium through which the heat is conveyed to the joint generally ; a feature of solder being that it is almost if not quite as good a conductor of heat as copper. The point will

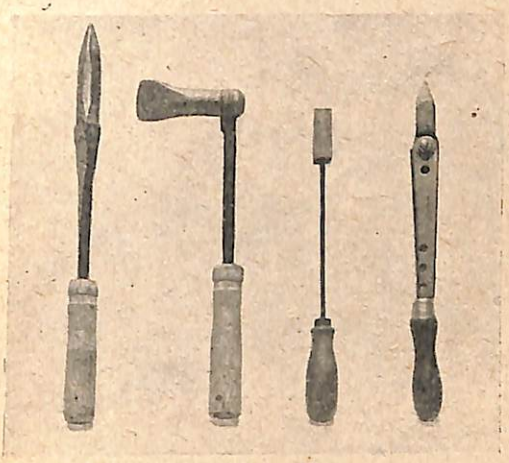


Fig. 1.—Group of Copper Bits for Soft Soldering

be unpleasantly brought home to the novice should he attempt to handle short lengths of solder when in contact with the bit. The heat will flash through it rapidly.

Other Soldering Bits

For general use the ordinary soldering bit already mentioned should weigh from a pound to a pound and a quarter, but for certain classes of work larger bits are useful as retaining more heat. The beginner, in this as in many other cases, is liable to err on the side of getting a " large one." With the heavy bit, delicate work is difficult, and the wrist

soon becomes tired. In fig. 1 (p. 15) there is also shown a hatchet-shaped bit, and after this a wedge bit, a light type, having the advantage of being mounted on a comparatively thin iron stem, which offers resistance to the escape of heat by conductivity. This type can also be obtained in the hatchet form. The long thin edge enables the more rapid running of long straight stretches of joint than can be accomplished by a pointed bit of equal weight. Another type of bit, not

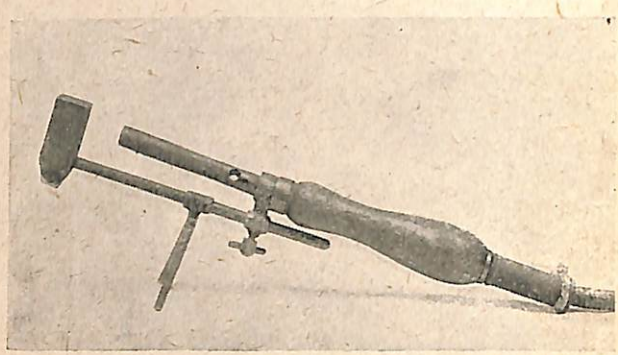


Fig. 2.—Gas-heated bit with detachable burner

shown, resembles the hatchet bit, so far as the shape of the edge is concerned, but it is mounted upright in a cleft shank, like the ordinary pattern. This is useful for the same purpose as the wedge bit, but is for heavier work. It is called a chisel bit. A bit with an adjustable end, which can be any shape and can be turned to any required angle, is also shown next in fig. 1. Although in the sketch the shaft looks heavy, it is not so in reality, being hollow and having holes to lighten the shank generally.

Gas-heated Bits

The soldering bit heated by an attached Bunsen gas burner offers an advantage to a novice because it relieves his mind from the necessity of thinking about keeping the bit hot. A curious fact that one notices with a beginner at

soldering is that by far the greater number of his failures are due to lack of sufficient heat in the bit, a trouble which a gas-heated bit helps to modify. On the other hand, a certain amount of inconvenience arises from the attachment of a flexible pipe for the conveyance of the gas, which naturally somewhat hampers the user. To an operator familiar with

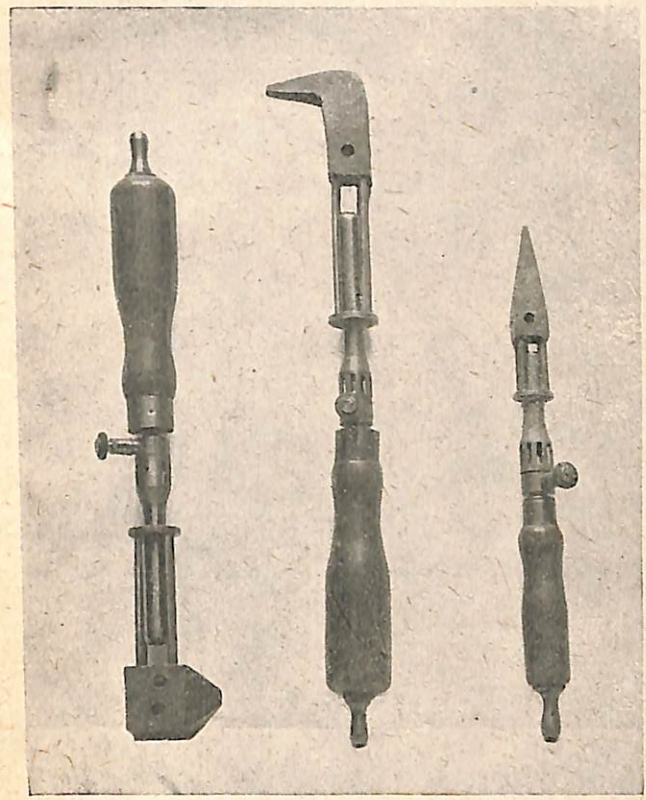


Fig. 3.—Types of gas-heated bits

the " irons," and who wisely uses a pair, one heating while the other is in use, the use of a separate gas heater is the more convenient all round.

Fig. 2 shows a useful little hatchet bit which is attached to a hand Bunsen burner, and has, in addition, a metal trestle to enable it to rest on a bench. The Bunsen and trestle are separately attached to the shank of the bit by screw-clips, allowing the entire removal of the burner which can then be conveniently used by hand to carry out local heating as described in Chap. IV. The Bunsen should have a full blast flame with a pronounced cone of green flame, which is then stiff enough to retain its direction on to the bit, even in spite

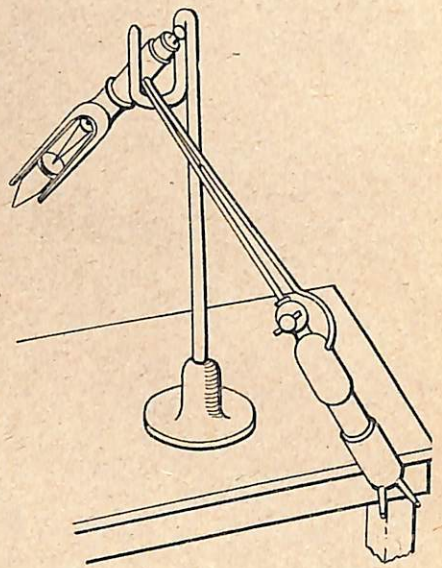


Fig. 4.—Combined gas blowpipe and bit

of moderate draughts of air. It should preferably be fitted with a fixed air supply. The connection for the gas is at the handle end, which is undoubtedly the best position. Fig. 3 shows three forms of another good type of gas bit. In all cases the burner is protected and plays into a hollow in the bit, which is drilled with holes to act as a flue or way through for

the flame. The left-hand bit in the photograph is a form specially made for the use of electricians. The burner is fitted with a valve control.

Bits of this description are not so serviceable for general miscellaneous work as for regular operations which have to be done at a bench, as, for example, making leaded windows, or alterations to stereotype plates.

One of the best gas soldering bits known to the writer is a form having forced draught ; a small gas blowpipe, in fact, in the cleft of the iron stem. It is lightly made and has a small copper terminal, as represented in fig. 4.

A pen-like form of the same kind of bit, which has been found serviceable for small repairs in difficult positions, is shown in fig. 5.

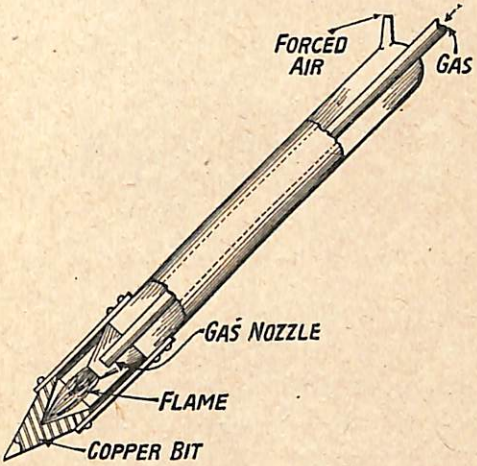


Fig. 5.—Pen-like form of blowpipe bit

Although there are numerous types of forced-draught blowlamps and gas blowpipes to be bought in the shops, which are referred to in the lists as suitable for soldering, they are really mainly intended and useful for heating ordinary bits only, when used in connection with soft

soldering. Their actual advantage in direct application to the work comes in in hard soldering, of which more later. There are several types of light forced-draught blowlamps working with methylated spirit or benzoline, which produce a flame in intensity and shape like the mouth blowpipe, which can be used directly in soft soldering; but, like the mouth blowpipe, they require very careful manipulation. Generally speaking, the power of a blowflame is far too high to apply directly to soft solder, as it results in the vaporising of the

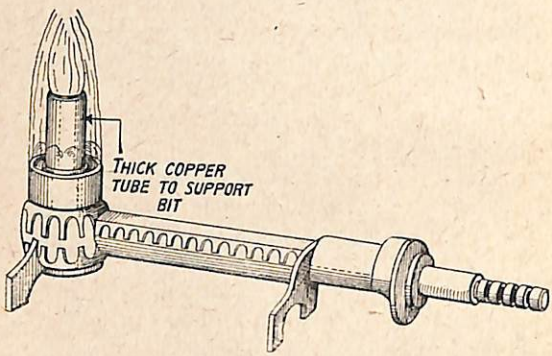


Fig. 6.—Simple gas heater

solder as well as the rapid oxidation of the metallic surfaces.

When gas is available, the most useful method of independently heating a soldering bit for general bench work is with some kind of Bunsen burner. Of the various kinds, perhaps the best all-round type is an ordinary ring burner, such as will also come in for boiling liquids or heating glue. It may with advantage be covered with a hood of sheet iron, which also covers the bit. For regular work, however, there is a soldering iron gas stove sold, which has covered provision for two or more bits, but otherwise is an ordinary Bunsen gas-jet. Failing gas, an oil-heated blowlamp can be used, but these lamps generally are sometimes troublesome to

start up. Fig. 6 shows a simple little gas heater, made up from a ½ in. " Argand " Bunsen, in which a circlet of smokeless flame plays around a copper tube ; the tube has a hollow top on which the bit can be rested when not in use ; this is illustrated in the figure.

Flame-heated Bit for Light Work

This is shown in fig. 7. It consists of a stout copper wire, pointed or chisel-ended at one extremity, and mounted in a

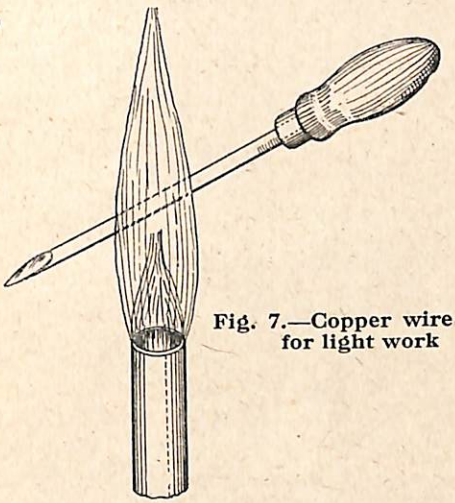


Fig. 7.—Copper wire bit for light work

wooden handle, or by preference the upper end is neatly wrapped in asbestos cord. By holding in a Bunsen or spirit flame, the soldering may be done with the projecting end, which is maintained at a constant temperature by conducted heat.

The device is sometimes made to fasten on the burner (fig. 8) so as to leave both hands free for the work, in which case a strip of some non-conducting material should be placed between the copper wire and the burner tube to prevent loss of heat by conduction.

It is sometimes convenient to bend the point, as shown by the alternative form. Naturally, in all cases the point must be well "tinned."

Obviously, the heat of the point can be regulated both by the size and position of the flame, but a loop in the wire as shown by fig. 8 ensures a better supply of heat.

The Mouth Blowpipe

This is a convenient source of heat in soldering small work (fig. 9). It is used to blow the flame of a lamp (oil or spirit),

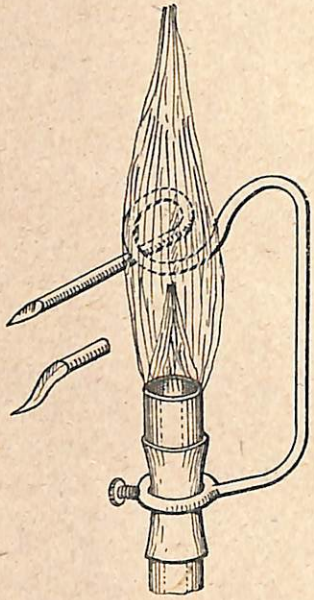


Fig. 8.—Copper wire bit fitted to gas burner

a fish-tail gas flame, or even a candle flame, upon the work to be heated.

A good example is illustrated by fig. 10, in which a lamp, consisting of a cylindrical metal vessel containing cotton wick saturated with spirit, or possibly oil, is fastened to

the blowpipe by a wire or metal strip. Fig. 11 also shows a similar but somewhat more convenient arrangement.

With such an arrangement the worker is enabled to hold both lamp and blowpipe in any position with one hand.

Although a very simple affair in itself, the manipulation and blowing of a mouth blowpipe are anything but easy. It requires considerable practice to dispose of one's breath between the necessary inspirations to the best advantage to maintain the heat in the right place on the work.

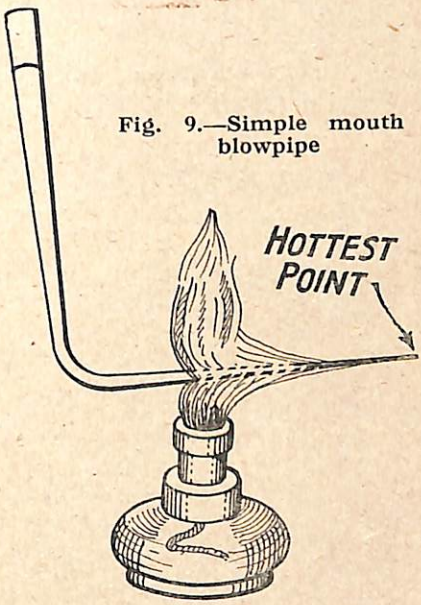


Fig. 9.—Simple mouth blowpipe

Electrically-heated Bits

These usually consist of a copper bit, set in a holder, in close contact with some form of heating element, which, in its turn, consists of a high resistance wire grid winding, mica insulated. The wire of these heating resistances is generally made of an alloy containing nickel and chromium, which, in combination with other metals, resists deterioration

under high temperature conditions. The wire, while having extra high resistance, as compared with measuring resistance wire, has but a relatively high temperature coefficient.

Fig. 12 shows a group of electric soldering irons made and sold under the trade name of the " Solon," by Messrs. W. T. Henley's Telegraph Works Co. Ltd. These are known as the " Empire " models, and illustrate two oval tapered bits

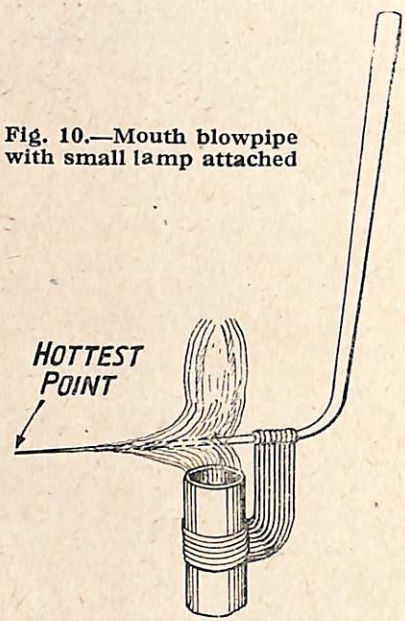


Fig. 10.—Mouth blowpipe with small lamp attached

(c) and (a), of 65 and 125 watt capacity respectively, and the two (d) and (b), with round pencil bits, of the same respective wattages. The two 65 watt bits are, in the main, 11½ in. long, but the pencil bit extends 1¾ in. further, making it 13¼ in. overall, and both weigh approximately 9¼ oz. The 125 watt size are 14 in. long, and weigh 1 lb. about. The adjustment of the pencils (which are both the same shape, but the larger made to be set slanting, with its edge horizontal) is by means of grub screws, and, beyond this, the con-

struction of all bits follows the same procedure of assembly. In order to remove a taper bit, or the corresponding pencil bit holder, the screw at the bottom end of handle (by the lettering) is removed, and the half bakelite handle comes away. The function of the live and return leads of the bit can then be broken, by removing the binding nuts and washers. The bit, or holder, is slotted on the inside, and takes, within the slot, the heating element fairly tightly. The leads down the stem are in one with the heater, and are bead insulated. Thus, when these leads are removed from their binding screws, and the fixing grub screw, or screws, at the top end of stem, are taken out, the bit, together with

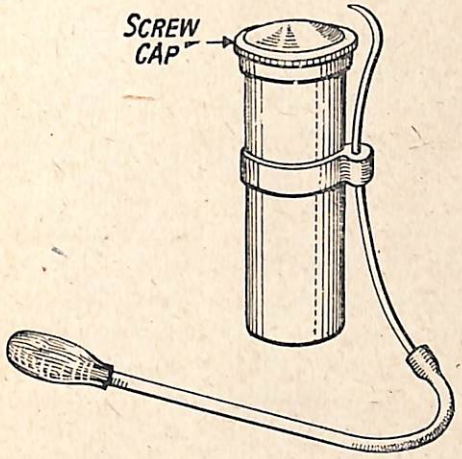


Fig. 11.—Portable lamp with mouth blowpipe attachment

the heater and bead covered leads, can be drawn. To replace a bit or heater, it is only necessary to slide the heater sideways out of the bit slot, when a new heater with its bead covered leads can be put in the slot, or a new bit fitted to the existing heater. The heater being fitted right into the enclosed tail of the bit, it is practically right on the job, but this advantage

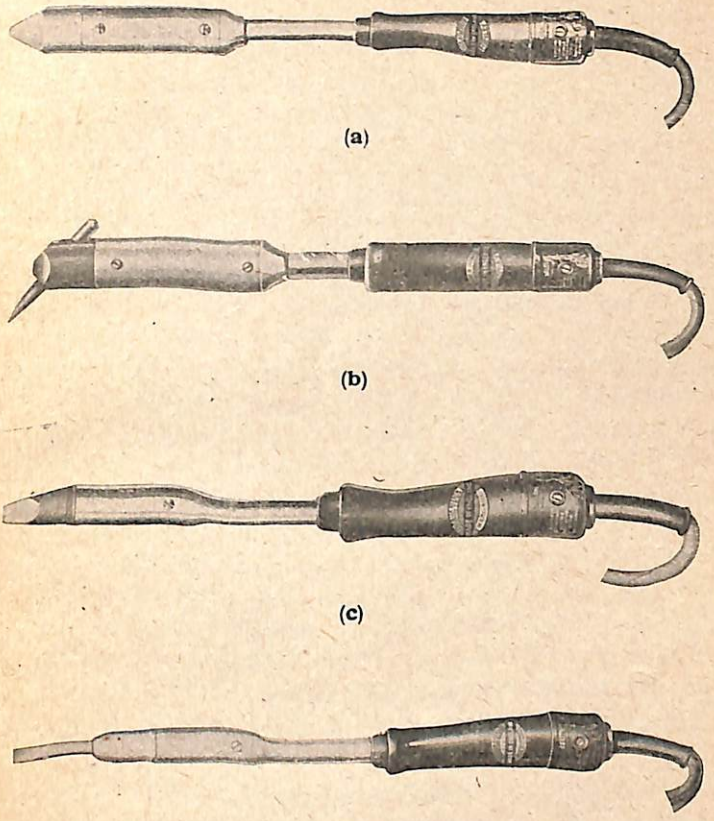
calls forth a warning from the makers to avoid the use of an acid flux. In respect of this matter it practically precludes the use of chloride of zinc (i.e. killed spirits) or even "Fluxite." The warning however is made to prevent careless users dipping the bit deeply, or splashing the flux into the bit joint. It should be clear that the voltage across the ends of the heater being anything above 200, the presence of acid within the heater will not only short-circuit the heater, but will set up electrolytic corrosion of the wires and thus destroy the heater long before its term of normal usable life, beside making it inefficient.

These "Solons" are supplied with 6 ft. of tough rubber sheathed 3-core flex, passing into the handle by a rubber cord grip, and the third core is an earth wire connecting the metal parts of the bit to earth. It is always supplied for connection, where possible through a 3 point plug, which is not supplied. The bits as a whole are generally accepted as among the best on the market.

Fig. 13 illustrates a cheap type of light electric bit made for 200 volts. It is 9½ in. long overall and weighs about 8 oz. together with its 3 ft. of flex and plug. This type of bit, which soon in its life developed an easily repaired contact break between the leads and the heater, has been in use for some five or six years now, used for odd work and very light work and appears to function now as efficiently as ever. It cost but a very few shillings but of course is only useful for quite small work.

The Standard Flux

The most important flux for soft soldering is chloride of zinc, a compound which is easily fusible and which covers the hot work as a melted layer or varnish. It is used in the form of a strong solution which is prepared as follows. The impure hydrochloric acid which is sold under the name "spirits of salts" at the London oil shops, and in the country towns chiefly by druggists, is a corrosive liquid which soon rots



(a)

(b)

(c)

(d)

Fig. 12.—Group of four types of "Solon" electric bits

Fig. 13.—Light electric bit for use on 200 volts

textiles with which it may come in contact, and will unpleasantly " burn " the skin ; but anyone who wishes to do all branches of soft soldering (or, indeed, any branch easily and satisfactorily) must obtain this liquid. It must be handled with care, and before use it should be " killed " ; or, to put the case more correctly, the hydrogen in the hydrochloric acid must be disassociated from the chlorine and water and replaced by the metal zinc, thus leaving a solution of zinc chloride. Pour some spirits of salts into a basin, which should be placed out of doors—as on the outside sill of a window—and into the liquid drop a few pieces of zinc. There will be a violent boiling up as the zinc dissolves and the hydrogen gas escapes. If the solution is made in the bottle in which the acid is bought, not a wise course, the zinc should be added very slowly ; and the bottle must not be corked or stoppered until the effervescence has quite finished. When the further addition of zinc causes no more bubbling up, bottle and label, " Soldering Solution." During the process, and while the hydrogen is being evolved with much energy, it is particularly advisable to keep the basin quite clear of any polished metal or finished mechanical apparatus, tools, etc., because it carries over and scatters about a good deal of the acid in a form of vapour, which readily attacks iron and steel.

Various Fluxes for Soft Soldering

In soldering lead, chloride of zinc is often rather a hindrance than a help, as a trace of chloride of lead is formed which adheres as a tarnish to the metal. For this work tallow is especially suitable. Again, resin or tallow may be used as a flux in soldering clean and bright tinplate, or in soldering brass articles which have been " tinned." Sal ammoniac is sometimes recommended for use alone or as an addition to the ordinary solution (killed spirit or chloride of zinc), but the writer has been unable to trace any advantage in its use. The use of special fluxes is described later in dealing with the individual cases of soldering.

Although zinc chloride is far and away the best flux known for soft soldering, it is not usually recommended for making electrical joints. It is argued that, should any of the flux remain free in cavities in the joint, what is known as " electrolysis " will be set up so soon as the electric current passes, and chemical disassociation will take place, with the possible result that the joint will be corroded and ultimately destroyed. Unless special fluxes be used, as referred to later, the general practice is to employ common resin as a flux for such work—that is, the resin which forms the residue from pine gum after the distillation of turpentine has taken place. The usual method in sweating a cable end into a thimble, after having fitted them, is to clean and tin, if necessary, the cable end, using resin as the flux, and hold the thimble opening upward in a Bunsen or blowlamp flame. On reaching a suitable heat, melt in and fill the thimble with a mixture of solder and resin ; the cable end may then be inserted and forced home, thus evacuating the superfluous solder and leaving a very sound joint on cooling.

Core solder, which consists of tubes of solder with a core of resin, or of any other solid or liquid flux, is very convenient. This form of solder can be bought from any plumber's merchant or ironmonger.

Resin and Tallow Fluxes

As hydrochloric acid and zinc chloride tend to the rusting of objects on which they are used, some tinware shops will not allow them at all. Others will only allow them for the first tinning of the bit ; and use resin or tallow afterwards. Let us suppose the bit to have been amalgamated or tinned in the first place by the use of the chloride of zinc flux (ordinary soldering solution), and to have been washed to free it from chloride of zinc.

After reheating, the nose of the bit is pressed into a lump of ordinary pine resin (so-called " rosin ") mentioned in Chap. IV., when the resin will flow over the end of the bit,

and put it in condition to take up more solder by capillarity. If, now, the joint on the tin is sprinkled with a little powdered resin, the soldering can be effected just as directed in the case of brass (see later). Tallow may be used instead of resin for the joint, but there is seldom or never any inducement to do this, except when lead is being soldered, as tallow on the finished article would ordinarily be more objectionable than resin.

Attention has already been called to the objection to the use of zinc chloride as a flux in soldering electric joints, but it may be used for tinning the bit in the manner mentioned above in soldering electrical work without any serious results. It is really the flooding of the joint with the flux in the actual running of the solder that gives rise to the trouble. The writer has made satisfactory joints in this manner by wiping the tinned end of the bit rapidly with a clean cloth after tinning with chloride of zinc.

Commercial Fluxes and Preparations

From time to time, during the last fifty years, various fluxes have been put on the market : some liquid, some fatty, and some containing chemical agents such as chloride of zinc emulsified with fatty matter.

All these may be convenient, but no flux of unknown composition should be allowed to remain on the work ; washing with hot water being in most cases sufficient to remove both chemical and fatty fluxes.

The Solder

The alloy known as soft solder is now required. The kind sold in ingots or bars about three-eighths of an inch square is generally known as " bit " solder, and ordinarily contains about 5 parts of tin with 3 of lead ; while that solder which is sold in thin runnings or strips is known as blowpipe solder, and it contains rather more tin, about 2 parts to 1 of lead with an occasional addition of half an ounce of cadmium or

bismuth to each pound of solder. This addition of bismuth of cadmium renders the solder more fusible.

Soft Solders of Graded Fusibility

These are useful in the case of a complex piece of work, the first series of soldering being with the least fusible solder ; while the last may, if required, be done with a solder which melts below the temperature of boiling water

1. Plumber's solder used for making wiped joints : tin, 1 part ; lead, 1 part ; melts at about 370° F. or 188° C.

2. Bit solder : tin, 5 parts ; lead, 3 parts ; melts at about 350° F. or 176° C.

3. Blowpipe solder without bismuth : tin, 2 parts ; lead, 1 part : melts at about 340° F. or 171° C.

4. Blowpipe solder with small addition of bismuth or cadmium : tin, 2 parts ; lead, 1 part. To each pound of the above add half an ounce of bismuth or cadmium ; melts at about 310° F. or 154° C.

5. Easy running blowpipe solder for general work : tin, 2 parts ; lead, 1 part ; bismuth, 1 part ; melts at about 245° F. or 118° C.

6. Fusible solder for pewter, just safe against boiling water : lead, 2 parts ; tin, 1 part ; bismuth, 2 parts ; melts at 236° F. or 113° C.

7. Wood's fusible metal : cadmium, 1 part ; tin, 2 parts ; lead, 4 parts ; bismuth, 7 parts ; melts at about 154° F. or 68° C.

Sodium in Soft Solder

If soft solder is melted in a ladle and small pieces of sodium (say as large as a grain of wheat) are dropped on the recently skinned surface, the sodium will be absorbed into the solder with a slight puff or deflagration. If from less than one-tenth per cent. be thus added, the solder acquires a remarkable power on slightly oxidising surfaces, as, for example, iron or aluminium, but the practical value of the sodium solder is

lessened by the fact that the joints made with it tend to corrode off or undercut, especially in the case of aluminium and such metals as are corroded by alkalies. For iron, the sodium solder is sometimes useful. Occasionally, a very fusible sodium solder is sold in the London streets as a solder which can be used on tarnished tinplate without a flux. Sodium solder is rather a chemical curiosity than of practical value, and those who have not a general knowledge of chemistry should not handle the pure sodium, as contact of sodium with water or with damp fingers may cause mischief.

The Preparation of Solder

Although formulae are given in these pages for all the principal soft and hard solders, it is not expected that every worker will make his own, though he may occasionally be glad to do so for some special purposes. The ingredients for soft solder may be fused together in an iron ladle and those for the hard solders in a fireclay crucible. In either case the solder may be cast into suitable bars or rods, moulds of well-baked clay being convenient in all cases. No flux is required in preparing soft solders, but a little borax should be used when fusing the materials for the hard solder.

CHAPTER III

SOFT SOLDERING WITH A "BIT"

LET it be required to solder a short length of brass tube to a disc of brass, to form a shallow round dish or a cap, such as is often used to cover the end of a photographic lens, or to make a box and a lid of metal. In fig. 14 the disc is first shown, then the ring. After all parts of the metal, where it is to be joined, have been scraped or filed quite bright, the ring (or short length of tube) is placed in position as shown next in the figure and all is ready for soldering. While an expert will join two little things like this quite easily, the beginner will find it an advantage to have the disc fixed with three or four small tacks to a holder (a bit of flat board) or held in a

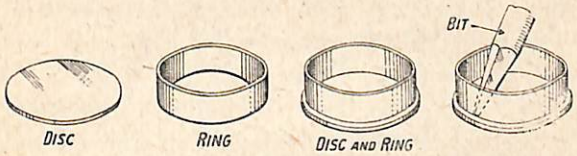


Fig. 14.—Soldering a ring to a disc

vice, and to have a small pair of pliers for handling the ring until the first solder contact has been made.

Preparing the Bit

Two egg-cups, each about two-thirds full of the soldering flux (see Chapter I) are required; in one of these there should be a piece of tobacco-pipe stem, about 3 inches long, to serve as a dropping rod. We also want a brick or tile on which the stick of solder (either the "bit" solder or the

blowpipe solder before mentioned) is laid. Heat the soldering bit in the fire until it is rather less than red-hot, and with a file quickly clean round the point to a distance of three-quarters of an inch. Many workers prefer to have a flat slab of grindstone on the bench and to clean the bit with a rub thereon instead of filing. The cleaned end is now instantaneously dipped into the egg-cup which does not contain the pipe stem, and is then brought down on the extreme end of the stick of solder. If all is right, the solder will melt and flow over the whole of the cleaned end of the bit ; but sometimes a touch with the file here and there, a gentle rub on the brick, another instant in the solution, and a second touch with the solder may be required. At any rate, the point and slopes of the bit must be thoroughly " tinned " or amalgamated before anything further is done. The bit, being well amalgamated, is laid at the edge of the fire where the heat will be maintained, but where the bit will not become red-hot.

All round the inside edge of the tube the clean soldering solution is applied with the dropping rod (pipe stem), so that all the parts to be joined are well flooded. The bit, as taken from the fire, is quickly dipped in the " dirty " solution (that which has been used for dipping the bit throughout) and brought against the end of the stick of solder so as to become loaded with solder, which will form a pendant drop at the end. Then the point of the bit is made to bear gently inside the ring, as shown in fig. 14. In these circumstances, the solder will run from the bit into the joint, and one point of the work will be tacked or fixed. Now tack an opposite point and then move the hot bit steadily round the circle in the manner described on page 14, so regulating the movement that the solder runs into the joint as the bit travels round. A thin stick of solder held against the bit will maintain the supply.

The bit should not be allowed to get red-hot, as excessive heat causes the tinning to sink into the surfaces of the point

and also to evaporate, thus rendering the copper at the point more or less spongy so that it will need thoroughly filing up to get a fresh surface for tinning. A small bit may be so worn by filing that it will lose in quantity and hence in heating capacity.

If it becomes necessary to lay the bit down, but not to heat it further, it should be laid so that the copper portion does not touch anything. Rather should it be supported by its iron stem. In this position it will not lose its heat so rapidly, but if the copper touches any conducting substance which it does not burn, such as metal or stone, it will part with its heat freely to that material.

Tinning before Joining

In the foregoing description the method given is that which would be adopted by an expert, but it is better for a novice to make a practice, as far as possible, of tinning the uniting surfaces before proceeding actually to make the joint. This sometimes gives rise to an ugly finish if the preliminary tinning is extended beyond the limit of the joint. In the case of the cap just described, it will be possible neatly to tin the end edge of the ring at any rate. To do this, it will be necessary to hold the ring firmly with a pair of pliers and rub or paint on a small quantity of flux on the end edge. The hot bit, properly tinned but not carrying a great deal of superfluous solder, should then be run round this edge, which will easily take a fine film of solder, almost like tinplating. Should too much solder be put on the tinned surface, it is not advisable to file it off when cold, but while it is hot if it is rubbed round with a bit of cloth the extra solder can be wiped off. This simplifies fitting the two portions together for the final soldering, which would be difficult if lumps of solder adhered to the tinned surface. It is not advisable to try to tin the disc, as it is difficult not to overlap the limit of the joint. Tinning one or both of the surfaces of the joint will facilitate the ultimate soldering considerably.

CHAPTER IV

SOFT SOLDERING LARGE ARTICLES

WHEN any article is so thick or massive that the soldering bit cannot carry sufficient heat to it, the general heating of the object becomes necessary. Let us suppose that our disc and ring are thick and heavy. The soldering bit might then deposit imperfectly adhering solder, without so far heating the material as to cause the solder to flow quite through the joint. In this case the work may be done by placing the ring in position on the disc and heating the whole uniformly. Before the cleaned and bright metal is so hot as to tarnish, the soldering solution is applied with the pipe stem, and the supply is kept up until the whole of the metal is hot enough to melt solder. A stick of solder is now rubbed round on the inside of the joint until sufficient is melted off, when the solder will run into the joint; if a few drops of solution are now painted on both sides of the joint, the solder flows so as to form a slight buttress on both sides. For applying heat, a tray of burning charcoal may be used or a clear ordinary fire, if the work is laid on a gridiron or suitable fork. Where gas is to be had, nothing is more convenient than a tripod and Bunsen burner as shown by fig. 15. Sometimes it is convenient to heat the work gently, or short of the melting-point of the solder, and then use the bit locally, as in our first example; but the method of general heating has considerable advantages for work in brass or copper. It allows keeping the fused solder for any required length of time in contact with the parts to be joined, whereby interfusion of the metals takes place; the solder penetrating into the

brass for an appreciable distance, and some of the brass alloying with the solder. This method of working is called "soaking-in," and in certain cases it gives a joint which cannot be undone by the application of a degree of heat equal to that originally employed.

Soft Soldering by "Soaking-In"

The method here described is specially useful where a joint has to be made water- or steam-tight. In a case where a plain joint of this kind is run with a soldering iron only, and especially where no preliminary tinning of the surfaces is resorted to, tiny air holes will persistently occur in the body of the solder, which do not become apparent until a leakage of water or steam shows them up. The method of soaking has the advantage of helping to eliminate these flaws and pin-holes in a joint.

Let the sketch in fig. 16 represent two pieces of brass tube which are to be joined. The parts must first be fitted, then

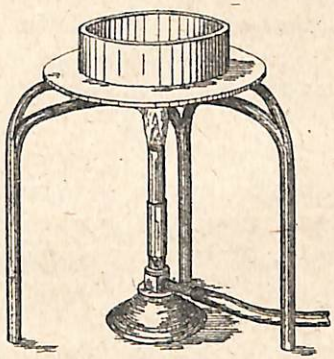


Fig. 15.—Soldering by flame heating

the contact parts must be amalgamated with soft solder by the use of soldering solution and the bit, or by heating the metal and alternately applying soldering solution and solder. Each piece must then be heated, and when the

solder is melted all excess is wiped off. Files (a flat for the outside and a round for the inside) may now be sparingly used for removing little projections of solder, or a metal scraper will be found most useful for disposing of superfluous solder in this and in many other cases ; but finally a " driving fit " is established, and one piece of tube is driven into the other. Soldering solution (the usual chloride of zinc or " killed spirit ") is now applied, and the work is heated somewhat above the melting-point of the solder. The solder is then applied at the joint, and if the work is kept hot for a short time there will be such interfusion of the metals that the joint cannot be undone. If this class of work is well executed, it is the most perfect form of soft soldering. For this particular work, a Bunsen burner that can be held in the hand is convenient for applying the heat, especially after the smaller tube has been inserted in the other. With the tubes in the vice, Bunsen in left hand, and the right at liberty to apply flux and solder, the work becomes very easy.

A type of hand Bunsen, suitable for this purpose, is illustrated as a part of the gas-heated bit shown in fig. 2. By the removal of the bit portion, and the supporting legs, to be described later, the appliance becomes exactly what is wanted.

Washing

Washing is necessary after the soldering is completed to remove the killed spirit or chloride of zinc flux. If the article is hollow or complex, the washing and soaking should be very thorough, and with such movements as shall drive currents through the various interstices.

Two separate vessels for containing the flux are suggested, because the flux contained in the vessel used for dipping the bit gets somewhat dirty after a time from the fragments of carbon carried to it from the fire, and from small portions of oxide from the bit. In actual practice, however, these have very little or no effect on the activity of chloride of zinc as a flux for the soldering when in strong solution.

Binding Objects for Soft Soldering

When a large number of small parts are to be soft soldered together, the operation would often be difficult, and occasionally impossible, if the parts were not fixed by temporary supports or " slave pieces." For soft soldering, the binding wire may be copper or tinned iron, and the supports may be

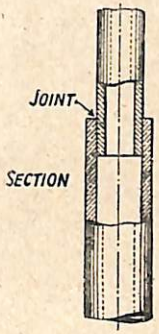


Fig. 16.—Example of joint for " soaking-in "

cut from stout tinplate, copper, or brass. A combination of general heating and bit work is often convenient for complex bound work ; and any slave pieces of wire which become fixed must be filed away after the soldering has been finished (see also later paragraphs).

Tinning the Bit without Soldering Solution

The bit may be tinned or amalgamated without using chloride of zinc at all. This is done by heating the bit to the required temperature, cleaning the end with a file, and immediately pressing the point into a lump of resin. The bit will then generally take a little solder, which may be made to spread by rubbing the bit on a brick on which some powdered resin is scattered. This friction lays bare some of the chemically clean metal, which the resin protects and keeps in condition to take more solder as this latter is spread. As an

aid to tinning the bit, a lump of sal ammoniac is sometimes kept alongside the lump of resin, and the clean and hot bit is first worked into the sal ammoniac. The sal ammoniac doubtless acts to some extent as a chemical detergent of the slightly oxidised copper, volatile chloride of copper being formed, but the delay in reaching the resin almost (sometimes quite) balances the advantage.

CHAPTER V

SOFT SOLDERING TINPLATE, IRONWARE, ZINC, AND LEAD

When tinplate is new and bright all solderings can be done without using the ordinary killed spirits (chloride of zinc), this often being a substantial gain, as nothing is left on the tinplate which conduces to rusting. Indeed, when the chloride of zinc flux is used for tinplate, a thorough washing, followed by careful drying, becomes necessary. None the less the novice will probably be the gainer by using a small quantity of resin powdered on the joints.

When tinplate is tarnished or worn, or when the best possible covering of the bare iron of the cut ends is required, the soldering should be done with chloride of zinc as a flux ; but, of course, this will only be used after the metal has been thoroughly cleaned by scraping, filing, or emery-clothing, to remove all traces of rust and scale. The finished article must be washed and carefully dried.

Soft Soldering Ironware

Tinplate is nothing but thin wrought-iron or low steel, which has been thoroughly tinned ; and, provided wrought-iron or steel is chemically cleaned, it can be tinned and soft soldered almost as easily as brass. But special difficulties step in when large and heavy articles are to be dealt with, as will be explained further on. Cast-iron is always difficult to solder, owing to minute particles of carbon constituting a semi-mechanical uncleanness.

In soldering bare wrought-iron, if only resin is used, it will

be found absolutely necessary to use a high and rapidly attained temperature to effect the joint before oxidation takes place, otherwise the use of zinc chloride will be found essential.

First Steps

Let the student commence by an experiment with sheet iron as thin as ordinary tinplate. This is moistened with the chloride of zinc solution, and, if the soldering is done with a well-amalgamated bit well heated, the solder will flow at once, and easily, as the thin metal is heated through almost instantly, and no appreciable tarnishing takes place. When the iron is thick and the heating is slow there is always a slight surface oxidation. In this case the sodium solder mentioned on page 37 may sometimes be used with advantage. If a thick piece of iron is heated over a gas flame, as recommended for brass, and is alternately treated with the chloride of zinc solution and solder, it will be found by no means easy to amalgamate or tin a large area, as a blackish film of oxide will form in places. In this case the best thing to do is to wash, dry, and scrub with a file card or other form of wire brush, before proceeding further in the operation of amalgamating.

Small articles of iron may be tinned by careful cleaning and immersion, first in melted tallow then in melted tin, and when projecting shanks of iron articles have to be prepared for soldering, the dipping method is a very useful one.

Soft Soldering Zinc and Lead

After what has been said about the use of soft solder for various purposes, but little need be said specially in relation to zinc. Sheet zinc is best soldered with the bit, and chloride of zinc as a flux, but it is often convenient to mix the chloride of zinc solution with one-fourth of its volume of " unkilled " spirits of salts or hydrochloric acid. This free acid dissolves the oxide from the surface of the metal, and more chloride of zinc is formed. Raw hydrochloric acid may be used with

zinc, the chloride of zinc then being formed at the instant of use, but the zinc becomes deeply corroded or etched, and sometimes the black deposit left undissolved interferes seriously with the soldering. In practice, the middle course (a mixture of hydrochloric acid and chloride of zinc) is generally best.

In soldering sheet lead or sheets of such alloy as consist mainly of lead—as, for example, the alloy ordinarily used in making organ pipes—the manipulation is nearly the same as

Fig. 17.—Shave-hook or scraper

in the case of tinplate. The sheets are laid together, and a clean edge is scraped with a shave-hook (fig. 17). The clean metal, which was laid bare by the shave-hook, is now rubbed with tallow, and the soldering is done with the bit in the same way as for tinplate. The making of stronger joints by wiping on a mass of solder is explained in another place later, as is also the method of autogenously soldering or " burning " lead.

In this case the metal must be clean on each side of the joint, and a very little hard tallow should be rubbed uniformly on the scraped parts, after which the bit is used as before, but the solder should be of a very fusible kind, No. 6, or even No. 7 (p. 31). While the joint is warm the tallow should be wiped off with a cloth. This kind of soldering is very rapid when all things are in order.

Cold Soldering

It is often important to be able to deal with a split or faulty iron pipe when in position. First clean carefully by filing and scraping—the latter especially in any longitudinal grooves—

next smear on tallow, and afterwards rub on sodium amalgam (a fluid amalgam, about 1 of sodium to 200 of mercury) with a large cloth pad, which well envelops the pipe. When the iron pipe is thoroughly amalgamated, a mass of a hard-setting amalgam is worked round it and finished off like an ordinary wiped joint.

A very suitable amalgam is the following : Melt together 1 part of bismuth, 10 of silver, and 20 of tin ; cast this into ingots and reduce to fine cuttings by means of a milling cutter used in the lathe, or by filing. The alloy is now kneaded with about twice its weight of mercury, or sufficient to make it easily plastic. In a day it will set firmly.

Unsoldering

As solder melts with heat, it seems obvious that any object can be unsoldered by heating it to the point at which the solder melts. As in so many cases, that which is obvious is only partly true. Often there is such interdiffusion between the solder and the parts joined as to make it impossible to undo or disjoin the work by mere heating. As a rule, however, tinplate work may be unsoldered by the application of heat, and in this way tolerably useful vessels may sometimes be made from old meat tins and the like.

CHAPTER VI

SOLDERING WITH TIN-FOIL

THE consideration of the use of solders for purposes of metallic ornamentation has been purposely omitted from this handbook by reason of lack of room. The question of ornamenting metal surfaces hardly begins at a knowledge of soldering, because it requires a trained artist craftsman to design the ideas as well as the methods of carrying them out. It is proposed, therefore, only to touch upon the possibilities of tin-foil in a process of " parcel soldering " metallic surfaces, producing a kind of metal inlay ; and, further, to show its application to a method of making nameplates, and how it can be used to make fine-soldered joints for special contacts in electrical work.

The Method of Using Foil

If a thin sheet (16 S.W.G. or thinner) of copper or brass be prepared on one side for soldering, after seeing that it is flat by polishing it and then getting rid of all traces of grease, it may have a design burnt-in in the following manner. Paint the surface entirely with a solution of zinc chloride, and while wet stick down one or two thicknesses of tin-foil (according to the depth of inlay required), taking care to cover all the portion intended to be inlaid. Upon the foil the design is set out. A good method is to take a tracing of the design, and, laying this on the foil with a sheet of carbon paper under, to trace the lines with an agate or steel tracer, so that the carbon reproduces the outline on the surface of the foil. It is then necessary to go over and cut through the lines on the foil

with a very sharp penknife, taking care not to shift the foil. After this, the spaces of foil representing the background are removed by raising the edges and peeling off. If now the plate be held over an ordinary upright Bunsen burner, with not too powerful a flame, taking care to follow the direction of the inlaid design, the foil will be burnt in or amalgamated with the metal surface. The actual junction will be indicated by a boiling-up of the foil, which must not be permitted to become too violent, or it will be left with a bubbled surface. After this, the whole plate may be polished, the design scraped or burnished, and the outline chased or engraved, with very pleasing results. Of course, the design may be removed and the background burnt-in, giving an opposite effect.

An application of the above for fine soldering nameplates is as follows : Suppose we require to build up a nameplate

Fig. 18.—Example of tin-foil soldering

like fig. 18. Procure a thin sheet of metal and prepare the letters and border-line. The letters, if plain, may be bought in a cast or stamped form, and the border-line built up of half-round or square rod, the corner pieces being a disc cut into four. Of course any combination of metal may be used : copper letters and border on a brass plate, or white metal letters, etc., on a copper plate and border, or *vice versa*. Ornamental letters may be fretted out from plate if the

reader fancies his own designs and can do it. In any case the plate is prepared and the foil laid, and as an additional security the under-sides of the letters, etc., may be thinly tinned. The letters are then laid in position and the foil cut away to their edges and the surplus removed as described. By mounting the plate on a tripod, or several tripods, if a large one, and directing a Bunsen on the under-side, the letters will then be fine soldered down, exactly in the position in which they stand, but the plate must, of course, be kept horizontal, or while the tin is liquid the letters may slide. One thickness of ordinary tin-foil will probably be found insufficient to make a sound joint, at least two being necessary.

Electrical Contacts Made by Tin-Foil Soldering

It sometimes happens that in constructing low-voltage electrical instruments and apparatus, it is advisable to use metals or alloys for contacts which are not so liable to oxidation as is brass or copper. German silver, standard silver, or even 15-carat gold or platinum may with advantage be applied. It follows that the expense of making whole fittings of such metals or alloys would be out of the question. The writer has made such contacts in electro-medical apparatus, using the baser metal for the fittings, and facing this with a thin film of standard silver, which was fine soldered to the body by a tin-foil joint. Suitable gunmetal screws were chosen, having cheese-heads, which were put in the lathe to face-off the slotted portion, leaving a smooth face either dead-flat or slightly hollow, not convex. A thin sheet of silver, say about $\frac{1}{64}$ in. thick, was purchased and cleaned on one side, after annealing, and a disc-punch chosen, the diameter of which was but a shade over the diameter of the screw-heads. The silver discs were punched from the sheet on a lead block as close together as possible to avoid waste. To make the joint a screw was clamped to the vice, held by its stem in lead jaws, with the head fairly high up to avoid

losing heat rapidly to the jaws. A little powdered resin was spread over the head, and two thicknesses of tin-foil in discs or little squares placed thereon. Then a little more resin, and finally the silver disc, clean side down. A heavy square bit, duly heated, with one of its flat faces applied to the top of the disc and pressed down (not sideways at all, for the disc will slide), resulted in a fine and clean joint of the silver to the screw.

It was found necessary to file the hot bit somewhat on the surface where it was intended to make contact with the silver to remove any oxide, as this acted as a barrier to the conductivity of the heat at that point. No doubt a very heavy and hot flat iron would effect the joint equally well, provided it was well scoured before application. By such methods as these, very thin and accurately-placed joints can be effected, entailing a minimum of labour in cleaning off superfluous solder, or otherwise finishing, subsequently to the making of the joint.

CHAPTER VII

ELECTRIC WIRE AND CABLE JOINTING

The Jointing of Single Electrical Wires

A GOOD general procedure is to flatten slightly the parts to be laid together, then to tin the ends and wash carefully to remove all traces of chemical flux. The flattened portions are now laid together and bound closely and neatly with fine-tinned copper wire ; after which resin is dusted on and the whole joint is filled in or flushed with solder by means of a suitable long-edged soldering bit. This is shown in fig. 19.

When Joint must not be Larger than Wire

In this case the ends must be somewhat reduced and also scarfed or chamfered, and the thin binding wire must be so selected as to bring the diameter to but a trifle over the finishing diameter (fig. 20). After having filled in or flushed the joint with solder, the surface may be rubbed down with a file until the binding wire is reduced, but as a rule not below half its original diameter. With care and judgment in the degree of chamfering and the selection of the size of the fine binding wire, the joint may be scarcely noticeable.

Joining Single Bell and Telephone Wires

Many electricians only twist the wires together, a highly unsatisfactory procedure, due to the liability of the contacts, which may be situated in inaccessible places, corroding, and thus introducing a break in the metallic continuity. They should, without exception, be soldered. First bare the ends thoroughly and get rid of all traces of the rubber or other

insulation by cleaning with emery cloth ; then tin the ends, which may be done with the soldering bit and zinc chloride ;

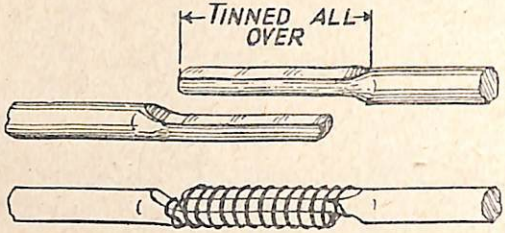


Fig. 19.—Simple joint of a single wire

that is to say, the zinc chloride may be used to tin the bit as before described. Flux will not be needed in jointing if it is clean and the bit is extra hot. After this hold the wire in a clean Bunsen flame, and when sufficiently hot wipe off all superfluous solder with a clean rag, leaving the wire ends with

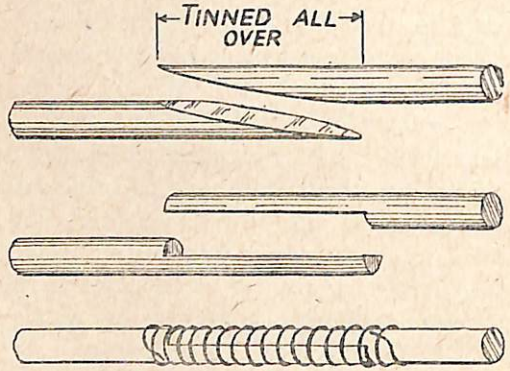


Fig. 20.—Flush jointing by scarfing and halving single wires

a thin bright plating of solder, which may be washed to free them from all traces of the flux. The tinned ends are then crossed over each other and twisted together. Not one wire twisted on the other, but each wire twisted in the other, so

that before soldering they cannot be pulled apart. Fig. 21 shows this. If much solder is left on them they are liable to snap in twisting. The extreme ends, which stick out, can then be cut off or hammered down. It only remains now to dust over the joint with powdered resin and to flush this through, using the bit as before described.

To make the usual running joint in single wire, used in general electrical work, proceed as described above, but only give about two intertwists of the wires. Then follow on by neatly binding the dead-ends of each wire round the other,

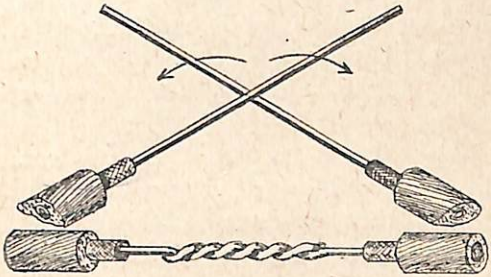


Fig. 21.—Simple twist jointing for single bell wires

spirally and tightly. The appearance when finished is shown in fig. 22.

Tee Joints in Single and Multiple Wires

Fig. 23 shows how a simple tee joint is made with single wires. Bare a portion of the main wire and prepare the end of the junction wire as in fig. 21. Tin a length, sufficient for the joint, in the centre of the stretch of main wire and tin the end of the junction. Give the junction wire one tight twist round the main wire and tack it on the outside firmly with a drop of solder. Then complete by winding the dead-end spirally on to the main wire and flush the whole joint with powdered resin and solder by means of the bit.

Fig. 24 shows a typical tee joint with triple wires used

where some degree of tension may be put on the joint. Having proceeded as for single wires up to the point of tinning, separate one wire of the junction cable and tin it ; also tin the other two. Now open a strand of the main cable and put the separated wire through ; tighten on it by twisting

Fig. 22.—The general form of running joints in single wire

up the main cable. Give the separated wire nearly a complete turn ; solder it tightly to the cable and cut off. The cable is then tinned for a length on the outside and the remaining two dead-ends of the junction cable twisted spirally side by side round it. The whole joint is then soldered up.

Mending a Broken Wire of a Dynamo Armature

Although the procedure will vary considerably according to circumstances, the following may be considered a standard method. A new piece must be inserted, a course which necessitates two joints, one or both of which may have to be of the same diameter as the original wire, as, for example, when a joint comes on the face of the armature. Any necessary scarfings and reductions having been made, also the ends

Fig. 23.—Bound tee joint in single wire

having been tinned and washed, the first joint can be made and finished under easy conditions. The most difficult case is when the final joint is on the face of the armature. A piece of talc is placed gutter-fashion in the groove (fig. 25) where the wire is to lie, and the chamfered ends are brought into position in the talc gutter, all slack at the ends of the armature being worked forward to the free ends, this necessitating

a tying with string or list round the armature endwise. Thin-tinned wire is now used to bind neatly together the chamfered ends as they rest in the talc gutter, the thin binding wire being threaded under and over the joint on the main wire, all the work being done with a minimum of slack

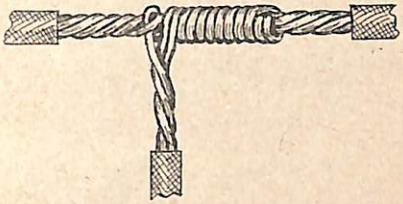


Fig. 24.—Tee joint in three-strand cable

on the latter. The binding finished, the joint is filled or flushed with solder as above directed and the temporary gutter of talc is replaced, if necessary, by a thinner leaf of talc. The wire is now drawn tight by wedging slips of talc under the ends, this being accompanied by an appropriate massage of the slack reach of wire.

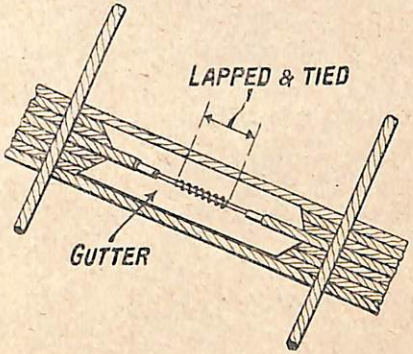


Fig. 25.—Isolating the final joint in armature repairing

Jointing Electric Cables

Cables consisting of numerous strands of wire are jointed similarly to the nautical method of splicing ropes, and are

afterwards soldered. The actual procedure in splicing need not be gone into here, but it is usual to bare the ends for an extra length so that the heat applied does not burn the insulation. The end wires are straightened and bent out radially for a length equal to the joint, allowing for the splicing, and are cleaned and tinned as described for bell wire. The splicing is then carried out, and at the moment of finally tightening and twisting the joint together, which is done while it is hot—being heated in a blowflame—it is

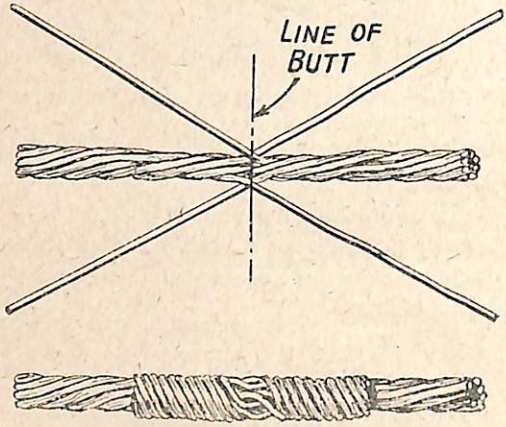


Fig. 26.—Running joint in a seven strand cable

flushed through with molten solder poured over it from a ladle. The flux used is a powdered resin.

Running Joints in Multiple Cables

The jointing of main cables constitutes a trade in itself, but electricians sometimes need to make running joints in seven-strand cables of small size wire. Fig. 26 shows in diagram form how to do this. Bare both ends for several inches and untwist most of the bared wire. Separate each wire and tin it all over thinly. Choose one wire as a core and put it in the centre, laying the other six round it tightly

for about a length of ¾ in. to 1 in. upon it. This makes the cable thinner. Now bend out sharply all six wires radially and cut off the core wire dead-short at the bend. The two ends thus prepared are butted together as shown in the upper view of fig. 26. The " spiders " of six wires each, bent out, are put interlocking with each other, and then each of the six wires forming the dead-ends are neatly spiralled round the thinned-out portion of the opposite cable and the whole flushed with solder as previously described. A small blow-

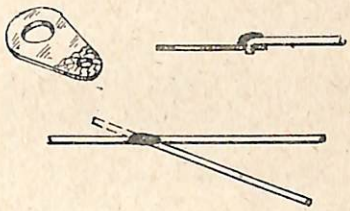


Fig. 27.—Simple " wireless " joints

flame helps a good deal in the final flushing. The lower view of fig. 26 shows the finished joint.

" Wireless " Joints

The character of the soldering in " wireless " receiving apparatus is very simple. Terminals of fittings are usually supplied with a small plated tab, shown to the left of fig. 27. These tabs usually have a small hole in the outlying end and are generally ready tinned. The bare tinned wire used in this apparatus is cut rather longer than necessary and bent down sharply to go into the hole of the tab. When thus fitted, it is cut off short enough not to project much downward. A drop of solder from the point of the bit is put on the hook when it is hooked in the tab, and only a mere film of " flux " is used to form the solder blob left. The view to the right which shows the section of the tab and hooked-in wire will explain the appearance of the joint (fig. 27).

In the same figure, at the bottom, is shown how to make a junction tee in wireless. Cut the junction wire longer than necessary in the first place. Locate the joint and put a spot of solder on the main wire and also on the under-side of the junction wire. Lay them together, holding the dead-end of junction with pliers, and tack them with the point of the bit. The dead-end projecting is then cut off flush with the main wire for technical reasons unnecessary to explain here.

CHAPTER VIII

PIPE JOINTS: SOLDERING AND "WIPING"

Soldering Iron Pipe to Lead Pipe

THIS is sometimes necessary, as, for example, when the end of a fixed or buried iron pipe is not screwed, and conditions preclude the cutting of a screw. The carefully-cleaned end of the iron should be greased with tallow, and a full and continuous stream of hot solder poured over it, when, as a rule, it will be tinned without difficulty. A previous amalgamation of the cleaned end with sodium amalgam (see p. 32) is sometimes helpful.

Soldering Brass Fitting to Lead Pipe

The least satisfactory way of soldering a brass fitting to a lead (or composition of tin and lead) pipe is the bit method,

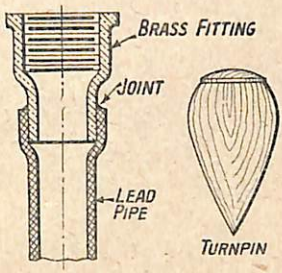


Fig. 28.—Bit method of soldering pipe joint

which is as follows: The shank of the brass fitting is thoroughly amalgamated or tinned (see Chapter I) and driven into the pipe as shown in fig. 28. The margin of the pipe

having been scraped bright, the scraped part is tallowed, and the soldering is done with the bit as in cases already mentioned. The blowpipe method is more satisfactory. The end

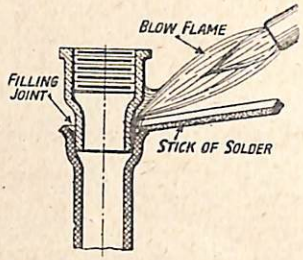


Fig. 29.—Blowpipe method of soldering pipe joint

of the pipe is swelled out a little by driving in the hard wood cone or turnpin, also shown in fig. 28, and the inside of the expansion is carefully scraped.

The clean metal now tallowed or covered with powdered resin, the tinned end of the fitting is driven into its place, and a blowpipe flame is directed on the joint, but more

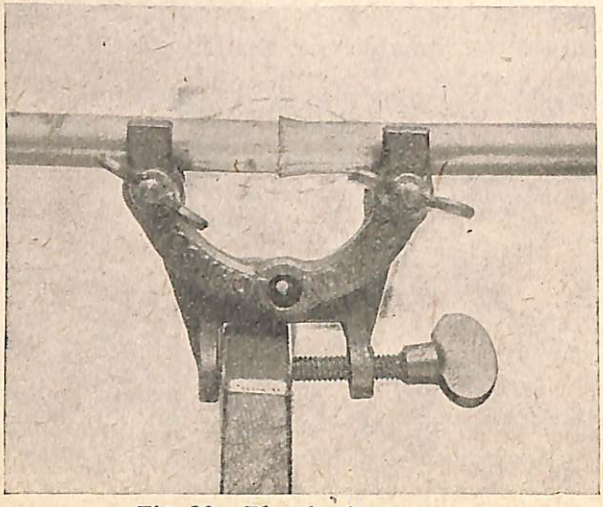


Fig. 30.—Plumber's cramp

on the brass fitting than on the lead, while a stick of solder is held in position so that as it melts the solder runs into the joint. The heat must be so adjusted that the solder flows freely into the joint, but the lead tube must not be melted. A quick wipe round with tallow at the instant of complete fusion smooths the joint (fig. 29).

The Wiped Joint or Plumber's Joint

This is a very ancient method of soldering pipes, and is the best when pressure is to be withstood. The principle involved

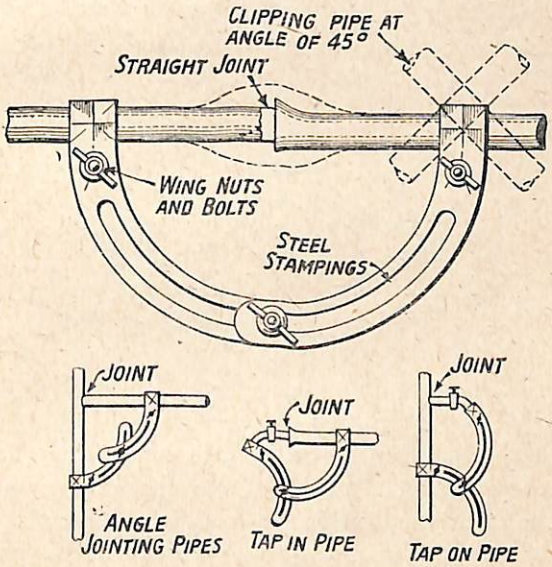


Fig 31.—An adjustable jointing clamp

is as follows: The clean metal on both sides of the joint is smeared with tallow, when melted solder (solder No. 1, p. 31) is splashed or poured on until the whole of the metal adjacent to the joint is heated to the melting-point of the solder. The solder will then flow over the clean metal, thoroughly amalgamating it. Some of the running solder is

now caught on the wiping pad held close underneath the joint; this wiping pad being a triple thickness of tailor's cloth, 4½ in. by 4 in., and well saturated with tallow. As the solder gathers in this wiper it begins to become crystalline and granular. It is worked round the joint and finished by wiping to the well-known shape, as shown by the dotted lines in fig. 30. The professional plumber usually fixes his work by some extemporised device, but the clamp shown, of which there are several sizes sold, is very convenient. An extremely convenient form of clamp, which can be bought at a very low price, is illustrated in fig. 31. So far as plumber's

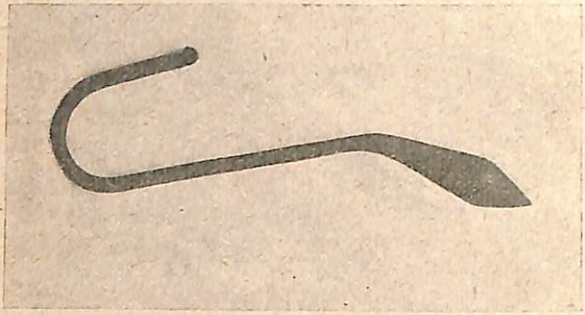


Fig. 32.—Plumber's bossing iron

work is concerned, the figure itself is explanatory, but the contrivance is also most useful for cycle-brazing purposes, and will be mentioned under the heading of "Brazing."

Adhesion of the solder beyond the intended range is prevented by painting (soiling) the pipes with a mixture of size and lampblack, and in scraping a sharp boundary is made between the soiled parts and the bright.

The fit of one pipe into the other, or of the tinned brass fitting into the pipe, should be as good as practicable, otherwise solder may run into the pipe. With proper care, reheating the joint for the final shaping will not be required, but occasionally it is necessary. An old means of reheating,

or rather of hardening and surfacing, is the plumbing iron or bossing iron shown in fig. 32, but a better means of reheating or softening is one of the many self-acting blow-lamps giving a large rough flame.

Wiping Seams for Sheet Lead

The principle is the same as in wiping joints on pipes, the boundaries being soiled, the area to be covered being scraped clean and tallowed. Sometimes the heating is by pouring

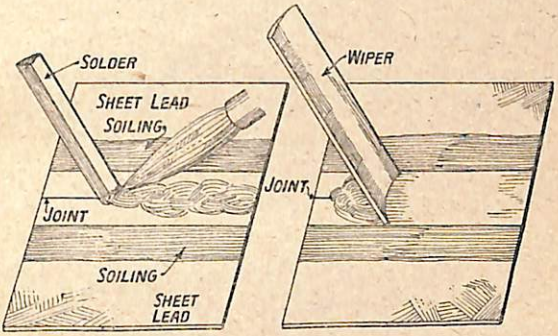


Fig. 33.—Wiping sheet lead joints

on the hot solder and allowing the excess to run off; in other cases it is very convenient to work as is shown in fig. 33.

A thick rod of solder is used, and the well-tallowed work is heated by a blowlamp to the fusing temperature of the solder, which is now rubbed and dabbed on freely; when this becomes plastic, the seam is shaped by a suitable wiper, which may be made of well-tallowed cloth for special work and inside corners, or of asbestos millboard, shaped as shown in fig. 33, to the right, for straightforward work.

CHAPTER IX

BRAZING OR HARD SOLDERING

Brazing solders are alloys more or less of the nature of ordinary brass ; indeed for iron or steel, ordinary brass or gunmetal or ordinary silver coin may be used, although generally somewhat more fusible alloys of similar nature are to be preferred. In brazing, the work is always heated to redness and the usual flux is borax, although the chemical expert may use cyanide of potassium. In the absence of anything better, the brazing of iron may be managed with common salt as a flux. The following is a list of brazing solders in the order of fusibility, the most fusible coming first :—

1. Copper, 24 ; silver, 24 ; zinc, 52 (*For soft brass.*)
2. Copper, 30 ; silver, 30 ; zinc, 40. (*For soft brass.*)
3. Copper, 40 ; silver, 40 ; zinc, 20. (*For soft brass.*)
4. Copper, 50 ; zinc, 50. (*For hard brass.*)
5. Copper, 60 ; zinc, 40. (*For copper.*)

Any of the above will serve well for iron or steel, the first three being types of the so-called silver solders.

The Operation of Brazing or Hard Soldering

The metal to be joined may be iron, pure nickel, brass, German silver, or gunmetal, but in any case it must be carefully cleaned, and when the parts are fitted binding with soft iron wire will often be necessary. Borax must now be applied (generally it is ground with water into a thin paste and painted on with a brush), and in many cases a little should be worked into the prospective joints before the parts are put together. The solder, in the form of wire or strip, may often

be bound round the joint at this stage, but is occasionally applied afterwards, and the heat is raised. A bed of charcoal is the best resting surface for the work which is to be brazed, and a gas blowpipe of suitable size the best means of heating, but a small forge of the ordinary pattern will often serve; while in some cases a clear kitchen fire will answer well for small articles, at any rate with brazing solders Nos. 1, 2, or 3. A pointed iron wire, amalgamated at the end with the solder to be used, is often of great service in directing the flow of the solder, and another wire cleft at the end by a long saw-cut and slightly opened out into Y-shape is of value in placing small pieces of solder in position.

Improved Methods

Hitherto the swelling of the hydrated borax has been the bane of brazing. This swelling often taking place with such force as to open joints even of strongly-bound work, but Sir H. C. Cunynghame's suggestion to use anhydrous or fused borax ground with ordinary paraffin oil (*Journal Society of Arts*, 12th January, 1900) obviates all trouble from this cause.

An excellent brazing flux sold under the name of "Boron Compo" has been found of great value in cycle-brazing. It is probably a compound of borax, as its name implies, being a compound of boron and sodium with oxygen. It has a peculiar grey-blue colour and is mixed to a paste with water for use.

In brazing any ordinary metal, except iron or pure nickel, care has to be taken not to fuse the work by overheating, and a brazing solder (see list) must be selected which melts at a temperature sufficiently low for the metal to be worked on. A preliminary trial is desirable in all cases of doubt. This test may be made by laying small pieces, even a few filings if no more can be had, of the metal to be worked and of two or three of the solders on a tile, heating the whole equally until one or more of the samples melt. To be safe the solder should melt at an *appreciably* lower temperature than the metal on which it is to be used.

When the metal to be soldered is a good deal less fusible than the solder, it is generally desirable to heat the work thoroughly first, and then to apply the solder, so as not to vaporise or burn away any of the zinc.

Shredded or carded asbestos, moistened with weak gum-water, made into a cake and dried is an excellent non-conducting and radiating support for work ; the same material may be shaped into jackets or heating-saving pieces for special work.

A Troublesome Case of Brazing

An illustration of rather difficult and troublesome brazing, and as an example embodying all difficulties likely to occur in practice, is the brass framework for the miniature glass case shown in fig. 34 ; a case in which articles can be set up

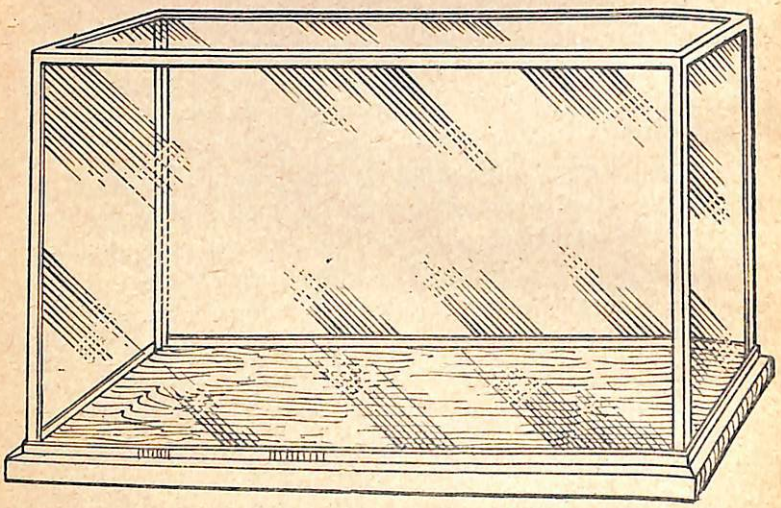


Fig. 34.—Showcase with angle brass frame

for exhibition. The framing of the case is made of angle brass, the section of which is indicated in fig. 35, approxi-

mately full size. As this moulding could only be obtained in a low melting-point brass, it was necessary to use a solder so near the melting-point of the work that unless strongly and carefully bound the brass would become deformed and the mitred joints would open. The supports took the form of angle-pieces of iron, about $\frac{1}{8}$ in. square, bound firmly on the brass with No. 20 soft iron wire, and a large gas blowpipe flame was used for brazing, a sheet of asbestos being held behind the work to conserve the heat. All portions of the supports or binding which adhere must be filed off after brazing.

For brazing there is a compound on the market consisting of a fine-granulated flux mixed with fairly finely-divided spelter, with which it is only necessary to make a paste with water to pack the joint for brazing.

Brazing a Small Steam Boiler

For purposes of realism in model-making the flanged ends of a small boiler may be riveted and afterwards brazed, but for all practical purposes it is really only necessary to braze the flanged joint, using pins as a means of holding the work together, because the joint, however well fitted before heating, is liable to become displaced owing to unequal expansion. Of course, low-pressure boilers can be soft soldered, but then only where in contact with the water. Fig. 36 shows a section of a typical joint at a boiler end, and also a tube joint. The boiler is usually mounted in the lathe and faced off square at the ends, after which the inside at the edge is thoroughly cleaned. The barrel may be of drawn brass or copper, while the end plate is of cast brass. The latter is put in the lathe also and turned on the flange, a good tapping-in fit to the inside of the boiler. After it is in position a few pins are fitted tightly right through the joint as shown in the figure. Holes are drilled slightly under size and the pins driven in. The metal for the pins must not be of lower fusing-point than the most fusible metal of the boiler joint. The nature

of the materials renders the use of a silver solder more suitable than brass spelter, as the latter would require a heat near the melting-point of the end plate if not of the shell. The boiler should stand end up on a brazing hearth, which may be charged with what are known as "asbestos nuts," small pieces of a compound of asbestos and fireclay. The

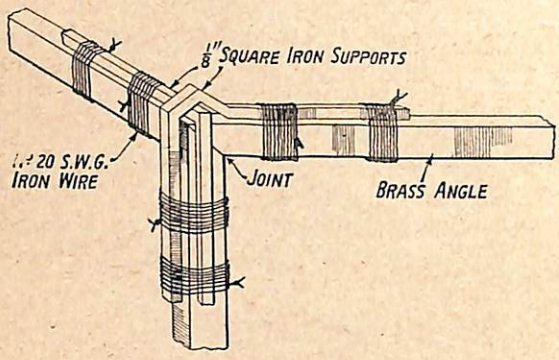


Fig. 35.—Method of binding joints for brazing angle frame

heating is best carried out by a forced-draught gas blowpipe blown by foot bellows, but a good blowlamp can be used. Borax mixed to a paste with water is first put all round the upper side of the joint, into which small pieces of the solder are distributed. The heat is then applied, and the whole end of the boiler is brought to a good red heat. The flame is then concentrated on one point, and as the solder goes down the flame is moved gradually round the joint to effect its entire filling. A piece of fine hard-drawn brass wire amalgamated with the solder at the point may be used to break up and guide the molten solder well into the joint. If properly carried out, the solder should penetrate the whole of the joint covered by the flange and should entirely solder in the pins both to the flange and the shell. If the latter is not effected, the pins may be blown out when the boiler is working under pressure. It is absolutely essential that the

solder should penetrate every part of the joint in dealing with small boilers, because it is largely upon the continuity of the metallic joint that the steam tightness of the boiler, and hence the maintenance of high pressure, depends. The frontispiece of this handbook gives a thoroughly explicit representation, supplemented by reference letters, of the general process of hard soldering a boiler end, and it will be noted that the solder is guided into the joint by a piece of iron wire flattened spade-fashion, and amalgamated at the lower end.

One of the essentials of hard soldering, or brazing, is that the joints should, in the first place, be a good pushing-in fit, and they should either be pinned as described above, or well cramped in relative position, because on application of the heat and consequent expansion, the parts are likely to move. If anything in the way of slackness exists in the joints to be brazed, the spelter is sure to run right through and drop clear of the space it should occupy.

The above particularly applies to the brazing-in of small water tubes in model boilers, as shown in fig. 36. After all bending and fitting is carried out the tubes should be cleaned and forced into their respective openings with such a tight fit that they will remain standing in any direction they are put without falling over.

Cycle-Brazing

This is always effected with good hard brass spelter, on account of the fact that the joints are either steel to steel, or steel to malleable iron, both of which can stand a temperature well above the fusing-point of any spelter. The usual method of making a joint is shown in fig. 37. Here the drawn-steel tube is made of a size to go into the lugs of fittings. As a general thing, these fittings are made accurately to dimensions, and require very little filing-up, either in the case of the tube or the fitting to make them a nice fit one to the other.

In these processes, as in all brazing operations, the

preparation for the joint, usually consisting of a paste of borax or special flux, such as boron compound, together with granular spelter, is put round the joint on the upper side so that on fusing it fills the joint below. It follows, therefore, that the arrangement of the joint must provide some sort of ledge or slot in which to put the compound. Spelter in the form of wire is useful for filling-in at a spot where a first application has failed to go, also an amalgamated steel wire can be used to guide the molten metal into the joint.

In cases where the tube is externally fitted and fits flush, which is not usual, the preparation for the joint must be put

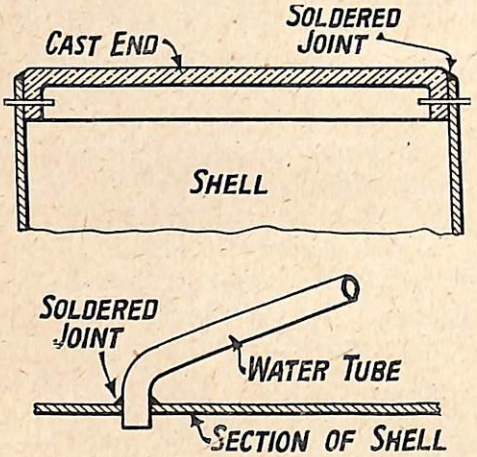


Fig. 36.—Small boiler joints

inside, and when a fitting is being brazed to a closed tube, one which has a fitting brazed to the other end, it is usual to drill a small hole through the tube in a position, not noticeable, to allow the escape of the expanding hot air which would otherwise be trapped and blow the molten spelter out of the joint or prevent it going in. It is usual also to pin the joints as already described, using fine steel pins about $\frac{1}{16}$ in. to $\frac{3}{32}$ in. diameter, because the actual relative set of the components

of a cycle frame is a matter of great importance. Failing the pinning, it is absolutely necessary to cramp the parts firmly in relative position, using a cramp like fig. 31. It should be remembered, especially in cycle-brazing, that where it is desired that the spelter pass into and fill up a fairly long joint, the heat must be simultaneoulsy applied and maintained over the joint as well as upon the spelter, otherwise the latter will solidify before going right through. It should

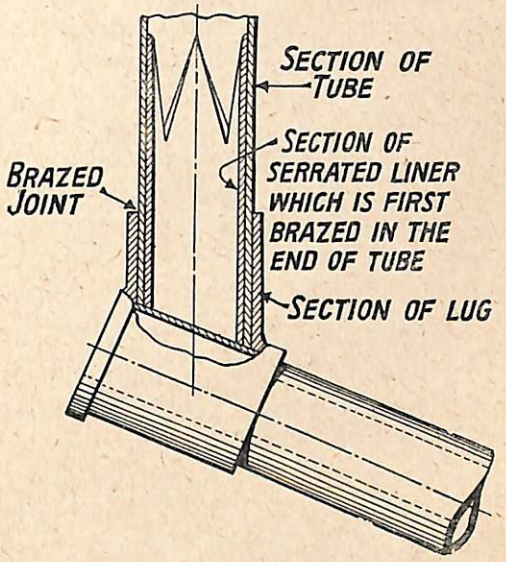


Fig. 37.—Cycle tube jointing

also be noted that to bring a comparatively long joint to a good brazing heat throughout, it is advisable to heat up the thicker parts at first before directing the flame on the lighter parts. The borax is usually applied to the opening of the joint after a red heat is attained, and the spelter in the form of brazing wire is directed as it melts in the flame into the joint which has already been penetrated by the flux. Where a method of soiling portions of the work is necessary to

prevent the spelter amalgamating, it is usually effected by applying a paste of powdered black lead and water.

It will be noticed in fig. 37 that a brazing liner is shown. These are introduced into and brazed to the inside of the tubes where the joint suddenly ceases, thus causing a sudden change from thick to thin, and hence a line of weakness. The liner which, from its shape, obviates or tones off this change is brazed into position in the end of its tube before the joint is made, and not simultaneously with the making.

It has been stated that, on occasions when the melted spelter persists in retaining a globular form, and cannot be made to flow in and around the joint, the application of a minute piece of soft solder will cause it to break up and run readily. Only quite a small piece is recommended, say, of the size of a pin's head, applied to the globule on the tip of a piece of flat metal. It seems feasible, whether the globule is the result of surface tension or of a fine film of oxide, that the sudden addition of the solder, which would immediately alloy with the surface and thus volatilise, would have the desired effect.

CHAPTER X

SOLDERING PRECIOUS AND REFRACTORY METALS: ELECTROTYPE JOINTS: GLASS TO METAL

PLATINUM can be soldered with fine gold (*i.e.* unalloyed gold), and as both metals remain chemically clean there is no absolute necessity for a flux; but borax is desirable as it partly balances the surface tension of any gold in globule form, and perhaps promotes its flow in other ways. Gold of various finenesses may be soldered by an alloy of 10 parts of gold and 1 part of zinc; thus to make a solder for 18-carat gold, melt together 10 parts of 18-carat gold and 1 part of zinc. In order to avoid loss of zinc by oxidation, the gold should first be melted under a layer of borax, and then the zinc is to be dropped in as a compact lump. Stir with a pipe-stem. The following will serve for gold ranging from 5 to 18 carat: fine gold 5, brass $2\frac{1}{2}$, fine silver $1\frac{1}{2}$. Hard solders Nos. 1, 2, and 3 serve for fine or standard gold, and such is the interfusion of the solder with the ware that these solders will generally give white seams of silver and German silver, or yellow seams with gold, and brass. This interfusion is a chief difficulty in hard soldering silver, and in a less degree brass, and it is best avoided by using a minimum of solder, heating the work equally by a large blowpipe flame and heating for as short a time as possible. If a drop or patch of solder is fused on a thin silver plate, the thin silver of the plate will alloy itself with the solder, become more fusible, and a patch of metal may drop out, leaving a hole. In brazing the angle of the brass frame (fig. 34), analogous interfusion

is likely to take place and a considerable portion of the brass may drop off unexpectedly.

Cold Soldering with Mercury

There is no true soldering under the fusing-point of the solder, but when mercury—which is always fused in our climate—is used as a solder for lead or type metal, interfusion slowly takes place and a fairly solid soldering may be made. Thus, if a stereotype plate is rubbed down with mercury on a mounting block and left under pressure there will be ultimate firm union.

So-called methods of cold soldering, involving the use of various metal filings mixed with acid, are not found to be at all satisfactory. They really produce what is known as "a rust joint" which is useful in some situations to make a water-tight joint. But no interfusion of the united metal surfaces takes place, hence the process is neither soldering nor brazing.

Practically the only kind of cold soldering worthy of the name is where metal surfaces are amalgamated with sodium amalgam and afterwards united with copper amalgam, which sets hard in the course of a few hours. The process is fairly simple, but the preparation of the amalgams is a lot of trouble not worth the taking, except where ordinary soldering is impossible.

Electrotype Joints

Another kind of cold union which may often be almost equal to soldering can be effected by depositing copper. For example, copper wires must be satisfactorily attached to the small platinum stubs which project from an incandescent electric lamp. A careful binding or tie with clean fine copper wire followed by a filling-in with copper deposited out of solution will give a joint practically equal to brazing. When copper is to be joined to copper by electro-deposition, the following are the most essential precautions : Let both pieces

be heated to redness to expel occluded gases, clean or file as the metal is cooling, when cold immerse in the electrotype bath, and finally, clean or scrape while under the surface of the liquid. Obviously, a steel scraper cannot be used in the sulphate of copper bath, but a strip of glass can be used. This course is impossible in some cases, but the nearest practical precautions should be taken to prevent the adhesion of air to the scraped surfaces.

Indeed, as a method of joining metals, electro-depositing one metal on another, as in electro-plating, or in depositing a metal upon itself, can be regarded as quite as sound a joint as soldering. And as some authorities state that when the relative metals adhere so firmly that they cannot be parted, even when burnished, they are actually alloyed, deposition may be regarded as a similar thing. The great drawbacks are that the processes are complicated and expensive, and that the need for scrupulous cleanliness is far greater.

"Soldering" Glass to Metal

F. W. Wenham has found that if soft solder or tin is melted on a metal plate, and a small piece of hot glass is slid across the fused solder so as to skim it, adhesion can be established by pressure; the operation being analogous to the making of a mercurial mirror. Button faces are in this way so firmly fixed on metal discs that the glass can only be removed by heating it.

Soldering Aluminium

Due to the fact that aluminium is so readily acted upon by the ordinary fluxes and oxidises so rapidly when made hot, it is practically impossible to unite it to itself or other metals by soldering. It is true that there are certain patented solders which are stated to effect a good joint. To all intents and purposes they do so, but it has been found that for the most part they are not durable and after a time give way. This may be due to the fact that the acid of sodium solder is

probably sought in these methods, and while it is a well-known fact that this solder will effect an amalgamation with aluminium, it is also well known that the ultimate joint does not last any great time. The writer thinks that a really reliable process of soldering aluminium is yet to be discovered.

Friction with the Bit as a Means of Cleaning

Occasionally it is stated that certain fluxes will specially conduce to the soldering of highly-tarnished metal, or even rusty iron. Broadly speaking, such statements require qualification, as friction with the bit is required to break down or rub off the rust or tarnish. Cleansing by friction with the bit is generally quite independent of the flux used.

CHAPTER XI

BURNING TOGETHER, AND VARIOUS METHODS OF WELDING

BURNING together, or autogenous soldering is the melting together of articles or parts of similar metal by heat, and the main factor is to provide something which may serve as a mould for the melted metal. If, for example, two sheets of lead are laid edge to edge on a tile or on a sheet of asbestos millboard, the metal at the same may be so melted by a red-hot iron or by a blowpipe flame that there is a uniform flow of lead across the seam ; a little more being added by melting in a strip of lead held in the hand. In making a vertical joint, the mould principle still holds good in a modified form. A block of fireproof material—say asbestos—is held at the back of the seam, and by means of a small and intense blowpipe flame (mixed hydrogen and air is commonly used) a round spot of metal on the seam is melted, a little more metal being added from a strip held in the hand. The melted spot of metal flows down and makes a thickened rib across the joint. When the operation is repeated about a quarter of an inch higher, a fresh quantity of metal flows across the joint, making another rib or thickening. In this way a vertical joint is made with great rapidity, the under-metal and the block at the back forming the mould, but sometimes a skilled lead burner will work without anything at the back, the under-metal alone acting as mould.

Articles of brass and cast-iron are often burned together by being laid in a mould and having a full stream of the fused metal poured across the joint. A blowpipe flame, ordinary

or oxyhydrogen as the case may be, will often prove useful for thus melting parts together.

Welding is practically the same as burning together, excepting that some amount of force is generally used to effect the joint. This may be either to perfect the union, as in the case of malleable metals, or to rupture the skin of oxide which forms, as in the case of aluminium.

Blacksmith's Welding or Shutting

This is an old method of joining wrought-iron and mild steel, and requires some considerable experience to judge the necessary degree of heat and also the particular shape of the ends to allow of hammering to the required shape. The ends of a rod to be joined are either scarfed or notched and pointed, having previously been upset sufficiently to give extra metal to allow of hammering out. The ends are then put in the fire

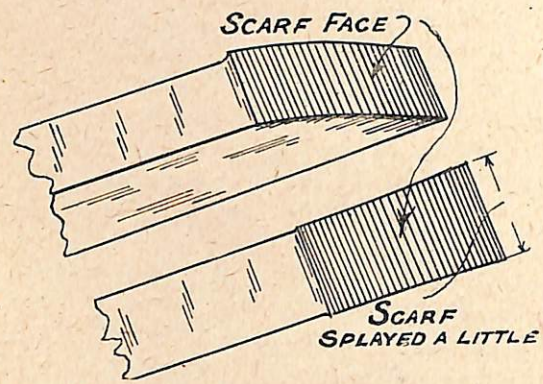


Fig. 38.—The scarf as formed for blacksmith's welding

and brought simultaneously nearly to the melting-point, to such a state that the metal is mushy and at a dead-white heat and throwing off scintillations. The pieces are then removed rapidly to the anvil, jammed slightly together and vigorously hammered all round the joint, the overlapping of the scarfing

or notching forming a lump, which gives ample metal to allow of the final hammering down to the original size of the rod. It can be realised that to shut a rod to a required length needs good judgment as to the length and shape of ends of the component pieces. It is usual to apply a little borax thrown on the hot metal at the moment of uniting. Sal ammoniac or sand are also sometimes used. It is not generally possible to weld cast-steel ; at any rate it cannot be done without altering its character for tool-making purposes at and around the point of junction.

There are other kinds of welding by hand hammer on the anvil, such as " Butt Welding," which is a definite butt joint, whereas " Scarf Welding," described above, is a butt joint made sloping for the better operation of hammering dead on the joint, as will be described by a sketch following. In any case butt welding can be better carried out by means of an electric butt welder, because it is a distinctly difficult operation carried out on the smith's method. " Lap Welding," as its name implies, is just lapping the metal and hammering it together. The latter resembles scarf welding, but is not nearly so accurate a method of jointing, because the lap is not so easy to hammer out to a definite length, and is really only adopted where the actual lap remains only part of the job. " Cleft Welding " is used mainly where the higher carbon steels are welded to mild steel or wrought iron. Because the latter welds only satisfactorily at a scintillating white heat, and the former must not be raised much above a good red heat to avoid burning it, the milder element of the joint is that cleft at the end, while the higher carbon steel is upset slightly and made blunt arrow pointed to fit the cleft. When raised to their respective welding heats and put together edge on the anvil, the hammering is then only done on the milder element on the outsides of the cleft side and side about. The actual shape of the sloping joints will resemble the scarf, for a purpose that will be described later. There are various kinds of building up

done by smiths all involving scarf or sloping joints, but this is more a reference to smith's work rather than just welding, but the method of "Jump Welding" may be referred to here. This is used where a plate has to be joined on to a shank, such as a very large flat bolt head on to the shank of the bolt. A conical indent is made in the centre of the plate, usually done by making it hot and punching the indent. The round bar to be joined is jumped up on end and made conical nearly to match the indent, or so that the point bears first in the hollow. Both are brought to welding heat

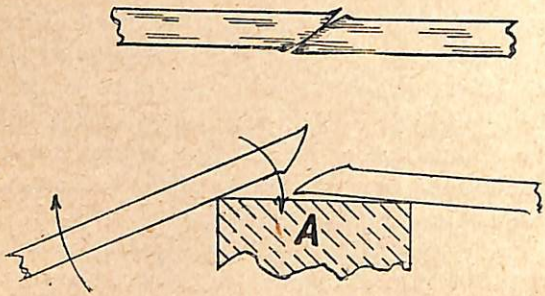


Fig. 39.—Position of scarfs and method of approaching it

and the weld effected by driving the bar in. The bar is made with the point to bear so that any oxide or slag formed on it is squeezed out. The last explanation also applies to the particular shape of a scarf.

Fig. 38 shows an actual scarf in two views. The two bars to be joined are first cut to butt a shade over length to allow for loss in scaling. Both ends are then upset (*i.e.* bulged out) slightly, and then are scarfed to the shape shown, which is tapered off down to a thin edge. This tapering can be done with a straight pane of the hammer or by the round edge of a fuller, working across leaving a more or less rough and lined surface as indicated. All this is done at forging heat. The weld is effected with the two rods set in relation as indicated in the top sketch of fig. 38 and the procedure leading

up to it is as follows : There are generally uneven pieces in a joint of which the smith takes the longer in charge and the drummer, or smith's assistant, the shorter which may be held in tongs. When both, in the same fire (not touching), are brought to welding heat and duly fluxed, on the scarf faces particularly, the assistant takes the shorter element and puts it on the right hand side edge of anvil as seen in the bottom view of fig. 39, giving it first a tap on this edge low down to shake off ash or any exfoliation. The smith follows suit with the longer piece, taps it on the edge and then brings it down smartly hinge fashion to the joint where it sticks, and he then follows with one smart blow which if properly delivered by a heavy hand hammer effects the interfusion. The scarf joint face, in this, and indeed in all welds, is made curved high in the centre, so that interfusion takes place here first and the subsequent hammering top and bottom and side and side drives out any molten flux, oxide, or other foreign matter, which would adulterate the interfused joint and most probably act as a flaw in it. In fig. 39 the lower view, where marked A, shows the anvil in cross section, the smith being to the left and the beak or horn of the anvil projecting at the further end. The curved arrows indicate the hinge-like action of the smith to place his joint in correct position, which will be slightly up the combined slopes as seen in the upper view of the same figure.

Aluminium Welding

This is practically the only method of truly joining aluminium and is not really very difficult. The change from the solid to liquid state of aluminium is very rapid, except that the formation of a strong film of oxide holds the liquid metal as if in a bag. If, therefore, ends of aluminium rods be held together and heated by a blowflame to the melting-point over as small a length as possible, and at the psychological moment are jammed together, the heating being simul-

taneously shut down or removed, the oxide skins will be ruptured and the projected liquid contents will run together and form a joint as strong, and in some cases—by test—stronger than the original rod. The superfluous metal will form a burr or ridge, which can be removed by filing or machining. The metal must not be heated over too great a length, or the joint will sag and ultimately break, emptying its fused contents before the welding can be effected.

Oxy-acetylene Welding, or Autogenous Soldering

During the past few years the method of welding or fusing together iron and other metals by means of oxy-acetylene flame has assumed considerable industrial importance. This process may be considered as being a system resembling lead burning, but with oxygen and acetylene instead of coal-gas or hydrogen and air.

The heat given by the oxy-acetylene flame is so intense as to render the local fusion of iron or copper easy, and strange as it may appear, the metal shows very little tendency to oxidise during the work. Oxygen is usually supplied to the blowpipe from a cylinder containing the gas under pressure, and the acetylene either from a gasholder or from a cylinder containing it dissolved under pressure in acetone. This mode of work is almost outside practicability for the worker of moderate means. It entails special plant and a workshop equipped with suitable optical observation glass and glasses to avoid eyesight injury, and, in a general way, needs its own operator, who requires to be a specialist. Although it may be regarded as about the most straightforward and simple method of welding, it is scarcely a general workshop method, being rather a production process.

Electric Welding

The principle involved in electric welding is somewhat similar to that of the electrically-heated bit—that is, the heat arises from the resistance of metals to the passage of the electric current.

In welding, the two pieces of metal are held in brass or copper clamps connected to the supply of current, the voltage of which is usually very low and is obtained by transforming down from a higher voltage ; the two pieces are then brought into contact with some pressure until the component metals commence to fuse, from which point the current is continued till the joint is made and then cut off. This, however, is

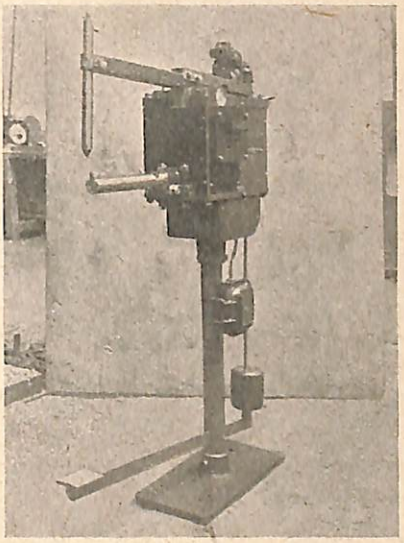


Fig. 40.—Pontelec 3 kVA spot welder

" butt welding," and an apparatus for this will be illustrated and described further on.

This description is merely an epitome of the process and must not be taken as being anything in the nature of working instructions.

Spot Welding by Resistance Action

One of the most well known resistance spot welders made is the " Pontelec " Spot Welder manufactured by

Messrs. Buckley, Sauders & Co. (Pontelec) Ltd., of Birmingham. The writer is familiar with the operation of one of these machines, which has been in use by Messrs. Claudet Limited, of Coleman Street, London, for a number of years, employed in joining the special metal and alloy metal contacts to steel contact screws used in ignition apparatus.

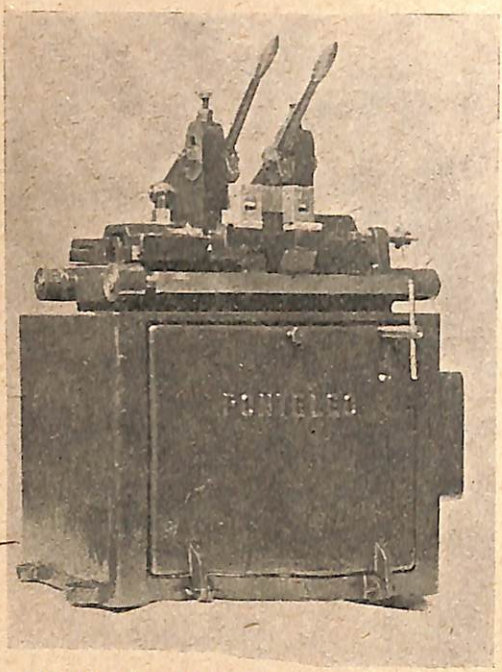


Fig. 41.—Pontelec resistance butt welder

Fig. 40 is a photo of this machine in its most recent form. The screw and its contact or other work is placed within the lower electrode, and the upper pointed electrode brought down on to the contact by the pedal, on pressing which the work is first gripped, then slight further pressure causes the switching on of current (probably of the order of 1,500 A at

2 V) and at the completion of the weld a further movement cuts off the current. The whole cycle of operation takes, on thin gauge materials, less than a second, and results in a weld stronger than a rivet. In the main it is a simple step-down transformer of the well-known high efficiency of such, but it is the accessory water cooling and constant spring adjustment of the electrodes, coupled with the trip switching fitted, that makes the apparatus such a successful working proposition in the speed of output. Obviously an electric energy of 3 kVA passing through a point produces such heating that it must not last long either on the score of joint formations or in the matter of economy in working.

Working on 24 gauge mild steel, which is higher resistance than the non ferrous alloys, the weld speed is given as $\frac{1}{2}$ second, and over 1,500 welds can be made per unit of electricity taken on the input side. That is without an automatic switch. There is, however, an auto switch that can be fitted, on which the operator has no control, and in which the time of current can be set at a predetermined rate, and with this, finely set, over the number quoted can be produced per unit by relatively unskilled operation. There seems little left to improve this machine, which can not only spot weld up to $\frac{3}{32}$ in. in mild steel, and correspondingly less thickness in relatively low resistance non ferrous metals and alloys, but can be used for closing over small rivet heads through a hole and even for heating up small parts for silver soldering. Another point is that it can spot anneal a hardened steel spring in order to punch a rivet or hook hole in it, but this is somewhat beyond the subject of the joining of metals.

The Pontelec Resistance Butt Welder

This machine in action follows the note as given in the first paragraph of electric welding. Two heads carry adjustable quick acting cam and lever gripping gears, seen at the top (fig. 41). The heads are mounted on a slide of which the left hand one has a fixing screw, and the right hand

one is actuated by an adjustable spring and lever with a Tee-head in right front of machine. The " at rest " gap capacity is then set by the left-hand head. In operation, the Tee handle is turned to right to open the gap by moving the right-hand head. Work is placed and clamped in the copper jaws with the butt joint midway between the heads. The Tee handle is turned to left contact, the weld made, and current automatically cut off. This machine works up to $\frac{1}{4}$ in. diameter in mild steel rod and equivalent rectangular work but this firm makes these machines up to 200 kVA capacity, which will work on considerably larger joints. Working on $\frac{1}{8}$ in. diameter M.S. wire the welding time is 1 second and 1,000 welds can be made per unit input of electricity.

At the opposite end of the scale—fine wire butting—such fine wires can be welded on the spot machine previously described.

For further details of welding equipment and methods, the reader is referred to the handbook *Welding and Flame Cutting*, also published by Percival Marshall and Co. Ltd. This describes in detail welding by the oxy-acetylene, electric-arc, and electric resistance processes, and also the cutting of metals by the oxy-acetylene flame method.

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